2000

An assessment of competing facility location optimization parameters: a case study of the United States Navy, Morale Welfare and Recreation Facilities.

Bowers, Charles Emery.

Monterey, California. Naval Postgraduate School

An Assessment of Competing Facility Location Optimization Parameters: A Case Study of The United States Navy, Morale Welfare and Recreation Facilities

by

Charles Emery Bowers, B.S.

Thesis

Presented to the Faculty of the Graduate School

of the University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Masters of Community and Regional Planning

The University of Texas at Austin

December, 2000

An Assessment of Competing Facility Location Optimization Parameters: A Case Study of The United States Navy, Morale Welfare and Recreation Facilities

Table of Contents

Chapter 1: Preface 1
  This paper is about… 1
  Why it's important 1
  Authors perspective 3
  Approach and Methodology 3
  Major sources of Info 4
  Form of final product 5
Chapter 2: Background 8
  Regional Planning 9
  Central focus: facility criteria planning 10
  Regional facility planning 12
  Organizational considerations 14
  Regional planning objectives 15
  Regional planning considerations 16
  Summary 17
Chapter 3: Literature Review and Methodology 20
  Types of accessibility measures 22
    Cumulative Opportunities & Coverage 22
    Gravity 24
    Random Utility 28
  Specification 31
    Spatial 31
    Soico economic 32
    Trip purpose 32
    Travel impedance 33
      Measure 34
      Mode 34
    Attractiveness 35
  Location Theory 35
  Customized to Navy problem 41
    Analytic solution not feasible 44
    Approach therefore is to simulate 46
    Form of equation 47
      Retail goods or services 48
      Entitled goods or services 57
  Summary 58
Chapter 4: Application: Using GIS for locational analysis 64
  Thematic mapping: Accessibility insights & problem comprehension 65
    Origin-Destination trips v. trip chains 66

Mode availability 67
Thematic mapping: a part of the whole 67
Methods operationalized 68
Step 1: Data collection and assembly 70
Step 1: Data collection and assembly 71
Regional data 71
Problem-specific data 73
Alternate data and possible sources 75
Step 2: Qualitative analysis 78
Evaluate region for areas of service member residential concentrations.. 79
Evaluate region for high use concentration areas 80
Evaluate residential location proximity to military installation areas & concentration areas 80
Step 3: Spatial analysis using Location theory 81
Step 3.1: Analyze region for acceptable levels of coverage 81
Step 3.2: Apply Huff model 86
Ready-made software solutions 95
Summary 99
Chapter 5: Conclusion 103
Ensuing studies 103
Concluding remarks 107
Listing of Bibliographic Materials 111
Vita 117

Chapter 1: Preface

This paper is about...

This thesis addresses U. S. Navy Morale, Welfare and Recreational (MWR) locational planning. Despite the fact that Morale Welfare and Recreation facilities constitute but only one aspect of the military establishment, they are a critical part of the military member's entitlements package that affects both military morale and retention.

Similar to other large organizations, the military's organizational structure and business practices are dynamic, constantly evolving to accommodate changing needs and expectations. However, the changing geopolitical environment of the post-cold war era has presented a particularly strong impetus for change. During this era the military's size, structure and resources have been significantly reduced. Accordingly, the Navy's MWR Facilities infrastructure must also be reduced both in terms of size and resources consumed. Yet as both a real and perceived part of the service member's entitlements, MWR services must be maintained if not improved. Addressing the conflicting objectives of minimizing cost while maximizing service comprises the focus of this thesis.

Why it's important

The close of the cold war, however, was not the only impetus for change. Concurrently, the role of government itself has also received considerable

attention.[1] Similar pressures to reduce cost while increasing service have been felt in the public sector at large. Much of this reevaluation has focused on the role of government in the provision of public services and has offered strategies of privatization, outsourcing and public private partnerships as a means to both increase government effectiveness and reduce cost. Thus, it is no coincidence that the Navy has also adopted these policy strategies. Accordingly, by addressing how service levels might be evaluated in light of constrained resources, this thesis provides a review of techniques that the public sector at large might use to assess its facility infrastructure and the spatial aspects of service provision.

From an academic perspective, this work serves as a bridge between the market-oriented field of location theory and the public welfare focus of accessibility measures. Despite the fact that business location models evolved from accessibility measures, their application to public uses appears to be largely overlooked. Conversely, market oriented evaluations will have increasing public sector applications as the public sector explores using more business oriented strategies such as privatization. This work covers three important issues.

1. It addresses a specific planning need for the Navy.
2. It outlines the link between accessibility measures and location theory.
3. And by means of an example, it discusses how the public sector might employ market techniques to improve its effectiveness.

Authors perspective

The author's perspective also influences this paper. As a Civil Engineer Corp officer, receiving a masters degree in Community and Regional Planning under the sponsorship of the U. S. Navy, much of the focus is on both the application of sound planning methodologies to the context of the Navy and furthering resolution to this specific problem of the Navy. As a result, this thesis illustrates the need for a planning perspective in the resolution of facility issues faced by the Naval Facilities Engineering Command (NAVFAC). Facility issues are larger than questions of bricks and mortar. They impact the lives of facility operators and facility users. Therefore, the answers to many of the issues faced by the Naval Facilities Engineering Command lie outside of the NAVFAC organization. The broad perspective of planners is uniquely suited to address these overlaps. In many respects planning represents the bridge between functionally segregated organizations (like the NAVFAC and the Navy's Morale Welfare and Recreation organization) that allows issues to be addressed on a comprehensive level rather than optimizing component parts at the expense of the whole.

Approach and Methodology

A literature review is primary means used to identify possible approaches to resolving the Navy's problems. The literature review provides an overview of accessibility measures and also discusses their use in more sophisticated measures

and theories. This provides the framework for the direct application of accessibility measures as well as a foundation from which those measures can be tailored for this Navy specific and other general uses.

A selection of accessibility measures and business oriented market location theories, considered appropriate to address the Navy's specific locational problem, is also provided. Although the suggested approach is believed to be a viable one, its compilation only serves as a general outline and not a complete resolution to the Navy's problem. The Navy Morale Welfare and Recreation program operates within a complex maze of statutes, regulations and policies. Moreover, Navy facilities are located worldwide in diverse regions with characteristics that vary from location to location. Customizing the suggested methods to address each of these details is beyond the intent and scope of this work. Thus a complete solution is only made practicable by incorporating the corporate knowledge base of the Naval Facilities Engineering Command and the Morale, Welfare and Recreation organization. Further, that input would be need to be gathered at both the Navy wide and local planning levels.

Major sources of Info

In and effort to provide the most practical solution possible Navy policy was reviewed and key Navy personnel were interviewed throughout the progression of this work. Particularly, where subject matter expertise was unattainable, the author's personal experience of nine years as a Civil Engineer

Corps Officer also served as a major source of information of what the needs of NAVFAC were and which methods might best meet those needs.

Form of final product

The end product of this thesis is a general outline of what is believed to be feasible means to address Navy related facility planning. The details of a complete plan are absent but a workable framework is provided. Although a complete plan is only feasible by tailoring the approach to the statutory regulatory, policy and numerous other specification issues by Navy subject matter experts the final product represents a workable plan. Further demanding an incomplete solution was that the Navy's impetus for reevaluating facility planning itself. Having only recently adopted an initiative termed "Regional Planning" many of the specifics of this initiative have not yet been resolved. Hence complete and specific implementation strategies are impossible to develop minus the shaping of specific goals. However policy outlining the Regional Planning initiative was reviewed at length to provide the most workable outline possible.

Maintaining an acceptable level of community support services and maintaining acceptable access to those services while simultaneously seeking economies of scale is a dilemma faced by most all levels of government, both in the military and in the public sector at large. Thus the outline also serves as an example of the role that accessibility measures and their associated issues play in

facility location rather than serving merely as a solution to a Navy specific problem.

[1] Savas, E. S. Privatization: *Privitization: The Key to Better Government* (Chatham, NJ Chatham House Publishers, 1987) and Osborne, Davide and Ted Gaebler, *Reinventing Government: How the Entrepreneurial Spirit is Transforiming the Public Sector.* (Reading, MA: Addision-Wesley Publishing, 1992).

Chapter 2: Background

New global, national, and geopolitical challenges face the Department of Defense and the Navy as the 21st Century opens. Over the past 20 years, the changing international environment has prompted considerable shifts in the size and structure of U.S. military forces. The prevalent philosophy of streamlining and realigning has worked its way throughout the Services. Today, leaner, exceptionally trained forces operate more weapons systems than in the past.

However, Navy leadership has concluded that although force structure has been effectively streamlined, associated infrastructure costs remain disproportionately high. To address this disparity the Navy turned a critical eye to the manner in which it does business and reasoned that major policy and cultural changes are required to significantly reduce infrastructure costs. This is in no way a trivial conclusion, for as defined by the Office of the Secretary of Defense (OSD), infrastructure encompasses ". . .those functionally organized activities that furnish resources for the management of defense forces, facilities from which defense forces operate, centrally organized logistics, non-unit training, personnel support, and medical services."[2] Accordingly, the Navy is engaged in a comprehensive assessment of its operating forces, policies, and support structures to determine its capacity to meet national obligations. Budget realities are compelling substantive changes to reduce infrastructure costs.

Regional Planning

As a result of these conclusions, the Navy has initiated a comprehensive regional approach to planning with respect to how infrastructure is managed in carrying out its mission.[3] Pragmatically the Navy has termed this initiative "Regionalization" and termed the planning aspects of Regionalization "Regional Planning". As might be expected from an organization that operates worldwide the Regionalization is executed at several different organizational levels. At the largest level the Navy has organized the shore establishment into twelve regions worldwide, seven of which are in the continental United States. Regionalization has also placed each Navy activity into a Navy Concentration Area (NCA) or designated it as a stand-alone activity. Major urban areas, like Norfolk, VA and San Diego, CA, where the Navy has several installations, largely define Navy Concentration Areas. It is at the NCA level where there is interaction between Navy personnel and commands that much of Regional Planning takes place.

Imbedded in this regional approach is a call to implement more efficient business practices both internally and externally. Along with other approaches it seeks to reduce redundancies through outsourcing, privatization, dual functional use of facilities, reduction of facility inventory and joint service use of infrastructure. Through these initiatives and in general practice, the shore establishment is responding to the reduction in fleet size and Navy budgets through appropriate reductions in the size and costs of infrastructure. A main

tenet of that evolution is to ensure shore infrastructure is lean and efficient, and in proper balance with force structure to satisfy the needs of the naval forces of the 21st century. In short, the Navy is seeking to run its "businesses" with a minimum amount of duplication and red tape and a maximum level of service and responsiveness.

The Naval Facilities Engineering Command is redesigning its land and facilities planning process to accommodate this revised focus. In the past, Navy land and facilities planning was done at a local level and was focused on developing master plans for individual bases. However, the revised planning process recognizes the need to emphasize comprehensive planning at a regional (primarily metropolitan area) level to realize economies of scale. It emphasizes land and facilities consolidation, demolition of aging facilities, and disposal of property. As the Navy's force structure has reduced in size and become more efficient, shore facilities must also reduce their footprint and maximize efficiencies.

Central focus: facility criteria planning

Although several policy instructions[4] have been issued to guide the development of regional planning in the Navy, implementation guidance remains to be developed. Naval Facilities Engineering Command (NAVFAC) Headquarters, Base Development Directorate, has identified revision of the Navy and Marine Corps Shore Installations Facility Planning Criteria Manual

(NAVFAC P-80) as necessary for the effective implementation of regional planning. The P-80 is divided into nine different series of facilities (Table 1). It is intended to provide quantitative planning criteria for determining the requirements for shore-based facilities needed to support Fleet and Marine Corps Operations. As used in the P-80, the term "criteria" refers to data used for establishing facility requirements and sizes. These criteria are used to evaluate the adequacy of existing facilities, to identify facility deficiencies or excesses, and to validate construction project proposals.

Table 1, NAVFAC P-80 Facility Categories

Series Code	Facility Category
100	OPERATIONAL AND TRAINING FACILITIES
200	MAINTENANCE AND PRODUCTION FACILITIES
300	RESEARCH, DEVELOPMENT, TEST AND EVALUATION FACILITIES
400	SUPPLY FACILITIES
500	HOSPITAL AND OTHER MEDICAL FACILITIES
600	ADMINISTRATIVE FACILITIES
700	HOUSING AND COMMUNITY FACILITIES
800	UTILITIES AND GROUND IMPROVEMENTS
900	REAL ESTATE

Source: Navy and Marine Corps Shore Installations, Facility Planning Criteria, P-80.

There are several purposes for this planning tool. One is to ensure that the existing and planned facilities are neither too small nor too large to accomplish mission objectives. Another purpose is to establish common planning standards between the Navy and other Services. As the Navy migrates to planning on a regional basis, it is anticipated that many of the criteria provided by the P-80 have

become obsolete because of its individual planning level focus.[5] This is anticipated to be especially true for community support/morale, welfare and recreation (MWR) type facilities. Accordingly, the 740 series of the P-80 (Community Facilities - Morale, Welfare and Recreational –Interior) has been chosen as the first series to be reviewed to accommodate regional planning.

Operational requirements criteria, or those directly related to the assigned operational mission, for the most part are not expected to require reevaluation in light of regional planning. The majority of the criteria for these category codes use as a basis for calculation specific inputs like number of aircraft (Maintenance Shops), throughput of students (Training Facilities), measurement tons of materials to be stored (Storage Facilities), etc. Therefore the criteria used to develop the regional requirements should be the same as the criteria used to develop the individual activity requirements in the old planning process.

Regional facility planning

Calculating Community Support/MWR requirements in the context of regional planning presents a different set of challenges. For example, where previously individual base master plans might have called for a gymnasium at each base, regional planning would analyze the requirement for gymnasiums across the region. The current criterion for gymnasiums is calculated based on base population (active duty military, civilians, retirees). In developing a regional requirement, the total regional population could be used to determine a

gymnasium requirement for the entire region. Given economies of scale it is anticipated that the regional requirement would be less than the sum of the gymnasium requirements for the former individual Navy activities of the region.

In essence, the question posed by NAVFAC is a two-part question. 1) Can economies of scale be realized through consolidation while maintaining acceptable access to, and provision of, community support services? and 2) What metric ought to be used to evaluate planning decisions made in a regional context?

The fact that NAVFAC is asking these questions suggests that it cannot expect to independently resolve all of the issues that arise from regionalization. These are not strictly facility-related issues, like those traditionally handled by NAVFAC, but they also have marketing and operational management aspects that question service strategies. There are questions about the design, operation and control of goods and service provision that require process-oriented investigations of customer service and quality. These marketing aspects will require input from and coordination with NAVFAC's customer, the Morale Welfare and Recreation organization, about its customers and competitors if rationalization is to bc successful.

Organizational considerations

Currently, user input into facility need determinations is only required for a few select types of facilities outlined in the Shore Facilities Planning Manual[6]

(Table 2). As subject matter experts, it is the functional commander's responsibility to review projects to insure compliance with statutory and other regulations specific to the facility type under consideration. But it is this type of user input for all facilities (not just those in Table 2) that is required for regionaliztion to succeed. It is the functional commander's expertise in regulatory requirements combined with their "business operations" familiarity that implicitly requires their input into the selection of an appropriate level of access to the service.

Table 2. Functional Commanders and Requirement Review Responsibilities

Functional Commander	Requirement Review Responsibilities
Bureau of Naval Medicine	Medical Requirements
Naval Supply Systems Command	Supply Facility Requirements
Naval Sea Systems Command	Shipyard and Shore Intermediate Maintenance Activities
Naval Air Systems Command	Air Operations Requirements
Chief of Chaplains	Religious Facility Requirements
Bureau of Naval Personnel	Child Development Center Requirements
Bureau of Naval Personnel	Brig Requirements
Chief of Naval Operations & Commandant of the Marine Corp	Navy Marine Corp Reserve Center Requirements
Chief of Naval Operations	Physical Security Requirements

Source: NAVFACINST 11010.44E, Shore Facilities Planning Manual

The Navy's Regional Planning initiative, where by assets close enough to provide mutual support are leveraged, establishes a new paradigm. It requires a multi-disciplinary and intra-organizational approach, developing a single comprehensive, long-range and strategic plan with realistic implementation

strategies. It seeks cost reductions for base support through the elimination of unnecessary management layers, duplicative overhead, and redundant functions.

In short, despite its responsibilities as the Navy's facility and real estate management agent, NAVFAC is but one player on the team required to implement Regional Planning. To genuinely "apply state-of-the market business practices"[7] as a means to "reduce the cost of the infrastructure"[8] NAVFAC will likely be required to abdicate the criteria establishing paradigm for a more corporate team, market-oriented approach where the customer defines the need and NAVFAC acts as a partner with the functional commander to fill those needs.

Regional planning objectives

Several tenets of regional planning itself have clear impacts on how facility criteria should be evaluated. In pursuit of reducing workforce-related expenses, including costs of goods and services, regional planning has finding "more cost-effective ways to provide perceived entitlements, benefits, and other quality of life services"[9] as one of its strategic goals. Three of the objectives outlined by the Chief of Naval Operations as a means to attain that goal are:

1. Partner with neighboring communities to eliminate duplicate functions inside the fence line.
2. Privatize, outsource, or civilianize where cost-effective.
3. Empower individuals to obtain entitlements, benefits, and other QOL expectations on their own.

A military installation is seldom situated in a location where there are no neighboring urban areas, communities or other military activities. Certain support functions, especially in the morale, welfare and recreational field, are not solely provided by the military, and the availability of such neighboring assets must be recognized in the planning process.[10] This characteristic directly impacts the number and location of facilities the military must provide to support a regional population. Thus, the facility evaluation must not only account for military service provision but also facilities available in the surrounding economy.

Regional planning considerations

The spatial diversity of Naval facilities, which are located worldwide, highlights the need to account for factors of disaggregation. Location specific factors, such as the degree of regional transportation system development, how the transportation system's loading varies throughout the day and the remoteness of a base, will vary largely from region to region in which the Navy maintains facilities. Other factors such as population and trip purpose can even vary within a single location depending on the population requiring the need or service. For example, shoppers looking for big-ticket items are often willing to travel further than those only seeking to meet their daily or routine needs. On the other hand, MWR/Community Support facilities which appeal to the single sailor or marine who may live aboard ship or in a barracks, should be geographically available without the need for a car, as it is reasonable to expect many in this population

base do not own a car. The criteria used to calculate these requirements needs to address these geographic and demographic issues.[11]

The old planning process, by virtue of planning exclusively for an individual base, provided facilities that were, for the most part, convenient to users of those facilities. Thus, the transition to a regional approach becomes a question of quantifying the cost-benefit ratio between efficiency gains from consolidation and reduced access of sailors and marines to the facility. The less time and money spent in travel, the more activities are available within a given budget.[12] This concern is particularly evident in the Moral, Welfare and Recreation facilities where facilities need to be located in reasonable proximity to the sailors and marines that they serve if they are to be considered an entitlement.

Summary

The following chapters seek to explore these issues. The focus is not to develop facility specific criteria but rather to develop a methodology for determining the criteria that meets the needs of the Navy. As implied by the questions above, the current impediment to revision of the 740 series of the P-80 is the application of a regional context to criteria development process[13] rather than the criteria development for each specific facility type. Additionally, the 740 series of the P-80 contains eighty-nine different facility types each with a different set of characteristics. Facility specific criteria development would require subject mater expertise in the operations management of each type of service provided by

each facility type. This is beyond both the scope of this thesis and the role of NAVFAC in general.[14] Although facility related issues are an integral part of the solution they are integral with operational management considerations. Accordingly, the objective of this thesis will be to unite established or theoretical techniques with Navy planning constraints (such as data availability and staffing) to create a workable method for criteria development. A literature review will serve as the primary means to identify possible techniques while a review of naval policy and interviews with naval facility experts will be used isolate which technique offers the most promise as a workable method for criteria development.

[2] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 4.
[3] U. S. Department of the Navy, Naval Facilities Engineering Command, *Comprehensive Regional Planning Instruction, Overview* (Washington, D. C., March 2000).
[4] U. S. Department of the Navy, Chief of Naval Operations, *Command Responsibility for Shore Land and Facilities Planning, OPNAVINST 11000.16A CH-1* (Washington, D. C.).
U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997).
U. S. Department of the Navy, Naval Facilities Engineering Command, *Comprehensive Regional Planning Instruction, Overview* (Washington, D. C., March 2000).
[5] Telephone interview with John Travis, Naval Facilities Engineering Command Headquarters, Base Development Directorate, Washington, D.C. 1 and 22 April 2000.
[6] Department of the Navy, Naval Facilities Engineering Command, *Shore Facilities Planning Manual: A System for Planning of Shore Facilities, NAVFACINST 11010.44E* sec 3.9 (Washington, D. C., 15 December 1987).
[7] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 3.
[8] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 3.
[9] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 18.
[10] Navy and Marine Corps Shore Installations, Facility Planning Criteria, P-80. (1998, March). Norfolk, VA: NAVFAC Criteria Office Engineering Innovation Division, Atlantic Division, Naval Facilities Engineering Command. Retrieved June 9, 2000 from: http://www.efdlant.navfac.navy.mil/Lantops_20/P-80/p80.htm
[11] E. M. Voges, and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators" (South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983).
[12] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1175.
[13] Telephone interview with John Travis, Naval Facilities Engineering Command Headquarters, Base Development Directorate, Washington, D.C. 1 and 22 April 2000.
[14] Navy and Marine Corps Shore Installations, Facility Planning Criteria, P-80. (1998, March). Norfolk, VA: NAVFAC Criteria Office Engineering Innovation Division, Atlantic Division, Naval Facilities Engineering Command. Retrieved June 9, 2000 from: http://www.efdlant.navfac.navy.mil/Lantops_20/P-80/p80.htm.

Chapter 3: Literature Review and Methodology

As noted in Chapter 1, facility issues are larger than questions of bricks and mortar. They encompass operational design issues. They involve service issues as they relate to facility users. They also involve variables arising from local area characteristics. Particularly, for MWR facilities that are considered part of the military members' compensation, access to the facility and the level of service it provides are fundamental to the facility's functionality.

Maintaining access to community support services is central to the issue of maintaining an acceptable level of those services while simultaneously seeking economies of scale. Access is a function of the geographic separation between demand and supply, travel mode choice, the ease of the commute and the amount and quality of activities at the destination.[15] The cost of travel is fundamental to accessibility. The less time and money required for travel, the greater the accessibility. Destination choice is also central to accessibility. The greater the variety of destinations, the higher the level of accessibility. Travel choice is equally important. The wider choice of travel modes, the greater the access to destinations.

Although, long recognized as a planning consideration, the concept of accessibility has rarely been translated into performance measures that can be used to evaluate policy or define criteria such as contained in the P-80. However, "because it accounts for both the [spatial] pattern of activities and for the links

between activities, [it] provides a basis for making trade-offs between land-use and transportation"[16] considerations.

Most measures of accessibility consist of two parts: a travel impedance (or resistance) element and an activity attraction element.[17] The impedance element reflects the ease of travel from the origin to the destination. It is affected by the quantity and quality of travel modes available and the cost of using them. The activity element reflects the spatial distribution of activities. Alternatively called "attraction", it depicts the amount and location of different types of activities. Although some researchers also suggest the importance of a temporal element; a temporal element is usually implicit in the changes of both the transportation and activity elements through out the day.[18]

Although a substantial amount of literature exists on accessibility measures no general consensus of their accuracy or application as an evaluative tool has been reached.[19] As Handy and Niemeier point out "An accessibility measure is only appropriate as a performance measure if it is consistent with how residents perceive and evaluate their community."[20] Because the elements of attraction and impedance are weighted differently by each measure, selection of an appropriate accessibility measure can be a rather tricky task of selecting the measure that most accurately reflects the elements that matter most to the residents themselves and not those that the analyst perceives to be important. Thus, a familiarity with the different types of measures and the characteristics of

each is required before they can be effectively applied. The following reviews different types of measures and then looks at the interrelated issues of specification, which must be addressed, regardless of which measure is employed.

Types of accessibility measures

Of the different measures commonly employed, most fall within three primary types: cumulative opportunities measures, gravity-based measures, and utility-based measures. Although each employs both a transportation element and an activity element, they differ in the level of sophistication with which they reflect travel behavior.

Cumulative Opportunities & Coverage

The simplest class of accessibility measures is the cumulative opportunities measures or contour approach. In this accessibility measure, a series of travel cost or travel time contours are drawn for each zone of trip origin and the numbers of relevant opportunities within each contour are counted.[21] This measure of accessibility can be used either from the point of origin counting the number of possible destinations or from a destination point counting the population in a service area. Although more complicated forms can be written to give less weight to shops relatively far from the trip origin, the cumulative opportunity measure can be simply expressed as the count of opportunities within a given distance as follows:[22]

$A_i = O_i(d)$

where

A_i = Accessibility at location i
$O_i(d)$ = the total number of opportunities available from origin i within the distance d from the origin to destination

Because of its simplicity the cumulative approach is an easily comprehended index without hidden assumptions.[23] A cumulative opportunities measure is often employed using a "threshold level of separation" boundary beyond which separation is considered too severe. The area within the threshold is commonly considered as a "coverage area," or the area for which a service is accessible. Accordingly, the term coverage area is generally reserved for counts taken from a destination, while the term cumulative opportunities is reserved for counts taken from a point of origin.

Being aggregate measures of accessibility, they are of limited utility for sub-area evaluation, because all opportunities falling within the same contour are evaluated equally. Thus no distinction is made between opportunities adjacent to the origin and those just within a particular contour, or "isochrone" of interest.Thus, from a behavioral point of view cumulative opportunity measures provide no indication for preferences that people have for one situation over another. Since opportunities are not weighed simultaneously by attractiveness and impedance, a system with near but inferior opportunities cannot be compared

to a system with further but superior opportunities.[24] Further arbitrary contour selection can provide deceptively large measures of accessibility.[25]

Gravity

The gravity model is probably the most popular accessibility measure.[26] The pioneering application of traditional physics-based Newtonian gravity models to studies of accessibility was done by W. G. Hansen when he tried to develop a land use model based on measures of accessibility.[27] Analogous to the pull of gravity between two bodies of mass, which weakens with distance, gravity models of accessibility weight opportunities (usually the quantity of an activity) by the effort needed to reach that opportunity.[28] Accordingly they appear in the following form.[29]

$$A_i = \sum_j o_j * f(c_{ij})$$

where

A_i = Accessibility at location i
o_j = the 'size' of opportunity at location j
c_{ij} = some measure of the cost of travel from i to j
$f(c_{ij})$ = some function of the cost of travel from i to j

Because there are many expressions for the impedance (travel cost) function $f(c_{ij})$, the gravity model is not actually a single model, but rather a

whole family of related spatial interaction models.[30*] Some common forms of the impedance function are presented in Table 3.

Table 3: Typical Gravity Model Impedance Functions

Inverse Cost Function	$1/c_{ij}$
Negative Power Function	$1/c_{ij}^{\alpha}$
Negative Exponential. Function	$e^{-\alpha c_{ij}}$
Gaussian, or normal function version	$e^{\frac{-c_{ij}^{2}}{\alpha}}$

Source: Voges and Naudé, Accessibility in urban areas; an overview of different indicators

The choice of the parameter α, which weighs an individual's preference for travel, is often rather arbitrary[31] for all forms of the impedance function, and may employ techniques such as using the squared distance between all points or using the diameter of the smallest circle that encloses the set of places.[32] However, calibration using survey data provides a more correct means to select α.[33] Alternatively, the value can be borrowed from previous area transportation studies or trip distribution models.[34]

Negative exponential functions are often favored over the inverse and negative power functions because they cannot be used in cases where distances or costs have a unit value of less than one and because the Gaussian function is perceived as difficult to estimate.[35] However, because Gaussain measures of accessibility are in the form of a familiar bell shaped curve that declines gradually

* A cumulative opportunities measure is actually a specific form of the gravity-based measure, with the impedance function equal to one if the opportunity is within the travel time limit and

at first, then more steeply with increasing distance from the origin, the Gaussian modification is often made in order to more realistically account for opportunities close to the trip origin.[36] Further, considering that these functions represent the decline in a person's perception of the attractiveness of an opportunity as the cost of reaching it increases, the Gasussian function appears to be the most behaviorally appropriate, because the other functions tend to discount the value of opportunities too rapidly with increases in travel cost or distance.[37] Additionally, when the Gaussian form is used, selection of the parameter α can be made a bit less arbitrary by substituting $2c_*$ for α. Using distance as a measure of impedance, this the model would have the following form:[38]

$$A_i = \sum_j o_j * e^{-\frac{1}{2}\left(\frac{c_{ij}}{c_*}\right)^2}$$

where

o_j = the 'size' of opportunity at location j
c_{ij} = the travel cost from origin i to destination j
c_* = the inflection point of the accessibility bell curve

When this is done, it can be shown using differential calculus that c_* will be the point of inflection on the bell curve. Although still somewhat arbitrary,

---

zeros otherwise (Handy and Niemeier, 1997 & Koenig, 1980)

this provides a method where by d* can be selected intuitively at the point at which separation appears to become difficult to endure.

A particularly common form[39] of the gravity function derives from Huff's (1963) expression[40] of the utility that a consumer derives from a shopping opportunity. He used this is expression to formulate his gravity-shopping model. In this model, Huff uses distance as a measure of travel costs and the square footage of retail space as a measure of attraction as follows:

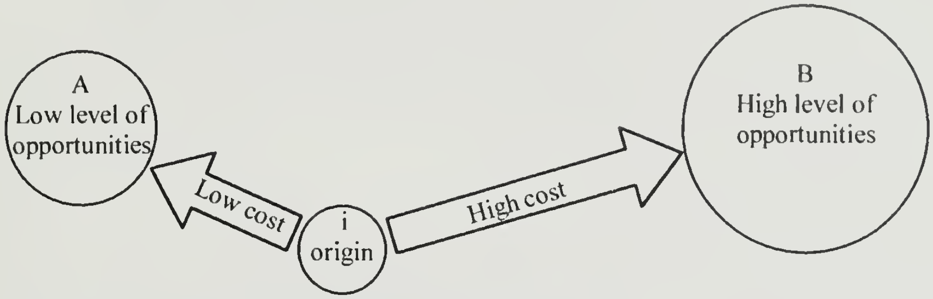
$$A_i = \sum_j \frac{o_j}{d_{ij}^{\alpha}}$$

where

A_i = Accessibility at location i
o_j = the 'size' of opportunity at location j
d_{ij} = the distance from location i to j
α = is a constant

Regardless of the gravity model form used, the primary strength of gravity measures is that they account for both attractiveness and impedance. Therefore, destinations with relatively low levels of opportunities and low access costs can be compared with destinations that have higher levels of opportunities but also higher access costs.[41] This is illustrated by Figure 1, in which destination A would the have an accessibility index similar to that of B.

Figure 1: Equivalent Gravity Measure of Accessibility of Two Destinations



Source: Voges and Naudé, Accessibility in urban areas; an overview of different indicators

However, this advantage can also be considered a drawback. Because the measure is biased by the weight given to opportunities or costs gravity measures are susceptible to manipulation. Additionally, because the model can yield similar measurements for different situations, it is often difficult to conceptualize the significance of particular values.

Random Utility

Random utility measures are the final class of accessibility measures examined. Utility measures use data about actual choice behavior to estimate individuals' preferences for one potentially accessible destination relative to that of all others.[42]

They are characterized by the following two assumptions:

- "People associate a cardinal utility with each of the alternative destinations which can be accessed from their place of residence.

- The utility of a destination can be represented as a sum of a non-random component and a random component."[43]

and accordingly they have the following form[44]

$$U_{ij}^{t} = V^{t} - C_{ij}^{t}$$

where

U_{ij}^{t} = net utility achieved by the journey from i to j.

V^{t} = gross utility of achieving destination for individual t (random variable)

C_{ij}^{t} = generalized travel cost or time from i to j for individual t (non-random variable)

Both the attractive element and the travel cost element are unique to each possible destination.[45] Thus, the utility function is specifically defined for each possible destination. Further reflecting the socioeconomic characteristics of the individual or household the utility function is uniquely defined for each individual t.

The denominator of the logit model for destination choice shown below provides an example of one form of utility function.

$$A_{ij}^{t} = \ln\left(\sum_{j=1}^{n} e^{U_{ij}^{t}}\right)$$

where

A_{ij}^{t} = the accessibility of individual t from origin i

U_{ij}^{t} = the net utility achieved by the journey from i to j for individual t as shown above in the utility function.

As with utility functions in general this form address accessibility on a very specific level. By incorporating the utility function, the accessibility measure is specific to the mode of travel of individual t but can be expanded to reflect alternative modes. When expanded, the accessibility measure is the denominator of a joint destination - mode choice model.

Utility measures of accessibility seamlessly incorporate socio-economic characteristics. Moreover, they provide a more detailed expression of impedance and attraction. Accordingly, they are generally accepted as offering the most explicit behavioral basis.

Of the models presented, utility models have the soundest behavioral approach. However, a major problem arises in their application because there is

no commonly accepted theoretical basis for selecting the probability functions.[46] To be useful, an accessibility measure must also be comprehensible. Thus because of its relative complexity and lack of consistent theoretical basis, when compared to simpler measures yielding similar results, utility measures are rarely justified.[47]

Specification

Selection of an appropriate metric implicitly requires resolution of a number of interrelated issues that isolate what specific aspects of access are to be measured. Factors including the geographic area for which accessibility is measured, the demographics of the population for which accessibility is to be measured and the purpose of the trip must all be isolated to produce meaningful measures of accessibility. The more precisely these issues are defined, the greater the accuracy of the accessibility measure. However, this requires more specific or disaggregate data. At least partly in recognition of the fact that the use of aggregate data masks many important details, more disaggregate and complex representations of accessibility have become increasingly common.[48] However, as the complexity of such measures increases, calculation becomes ever more costly while interpretation becomes progressively more difficult.

Spatial

Given the spatial nature of accessibility, spatial disaggregation is possibly the most fundamental specification issue.[49] Typically, accessibility is measured

by zone. Accordingly, the smaller more disaggregated zones generally produce more accurate measures of accessibility. However, this accuracy comes at a cost. Smaller zones represent more data computation costs.[50] Moreover diaggreagate data may not be available.

Soico economic

Given that the costs of overcoming spatial separation and the attractiveness of different opportunities are viewed differently by different income groups,[51] socio-economic disaggregation is also an important consideration. Although disaggregating individuals or households by some characteristic should produce more accurate results, the level of required disaggreation has practical limits.[52] Thus selection of an appropriate level of disaggregation becomes a balance between the cost of obtaining disaggregated population data and the accuracy gained.

Trip purpose

Largely associated with the trip destination, the purpose of the trip represents yet another dimension of disaggregation. While at the most aggregate level the number of opportunities regardless of type is counted, generally only a specific type of opportunity is of interest.[53] For example if accessibility to shopping centers were the single concern, only shopping destinations need be counted. However, the set of destinations is also dependent on individual assumptions as to what residents perceive available to them.[54]

The point of origin represents another associated disaggregtion factor. Historically, most researchers have used home-based models, assuming trips begin and end at home without accounting for other points of origin such as work. Accordingly, multipurpose trips and trip chaining have also been highlighted as an important limitation of a home-based focus.[55]

The distinction between origin and destination also introduces the concept of relative and integral accessibility. Relative accessibility is the degree to which two points are connected.[56] Depending on the origin and destination, relative accessibility may not be the same for the same set of two points. Considering accessibility in a network of one-way streets highlights this notion. Conversely, integral accessibility is defined as the degree of interconnection for a given point with all other points on the same surface.[57] In other words integral accessibility is the sum of all possible relative accessibilities from a given point. Although this distinction is important, it is often not made explicit and integral accessibility, the more commonly used of the two, is often what is what is meant when the term accessibility is used.

Travel impedance

The measurement of the travel impedance element of accessibility measures bears two specification issues. Variations in both the units by which the impedance is measured and dissagreation of travel modes will mold the results of the accessibility measure.

Measure

Spatial separation may be measured in terms of travel time, distance, cost or some combination of these or other characteristics. Each of these may be derived in different ways. For instance, estimates of travel time may either be measures of perceived travel time, as reported by respondents in home interviews, or estimates of network travel times obtained by shortest path algorithms. Unfortunately, systematic errors are associated with every approach and the problem becomes one of choosing the measure which best suits the problem at hand from the available alternatives.[58]

Mode

Differences in travel time and cost arising from different modes of travel are another important consideration. Accessibility measures calculated for transportation by automobile would be useless if only public transportation was available to a large portion of the study population. Accordingly, the short-run impacts of particular land-use/transportation plans may depend substantially upon the mobility characteristics of the population. One approach to addressing this issue is to calculate separate mode-specific accessibility indicators based on knowledge of actual travel patterns, which can then be compared.[59] The incorporation of both the multimode travel costs and multimode opportunities highlights to advantage of utility measures despite their difficulty to formulate.[60] Because by definition utility measures of accessibility account for travel costs for

each specific individual, they are particularly well suited to account for differences in mode of travel. However, in light of their complexity, this advantage is not generally viewed as justifying their use.

Attractiveness

The final specification issue concerns measuring opportunity appeal. The choice of appropriate attractiveness variables will depend upon the specific activity or group of activities under study.[61] The existence of a particular opportunity as measured by a simple cumulative opportunities count may be appropriate or it may be that a destination's physical or economic size as measured by the area or revenue generated may be more a more appropriate measure. Shopping behavior research suggests that factors such as the quality and price of products or the quality of service, could be incorporated into a measure of attractiveness. "Such characteristics are highly subjective, however, making it difficult to both specify and calibrate the accessibility measure."[62]

Location Theory

As the reader may suspect, accessibility measures can be employed in numerous ways to evaluate any number of spatially related issues. Having reviewed the fundamentals of accessibility measures, customized applications of accessibility measures for specific problems can now be examined. In 1964, David Huff hypothesized that the probability that a resident of zone i would shop in zone j was formed by a ratio of their access to the shopping location at zone j,

divided by their access to all possible shopping locations (including the location of interest j).[63] Note that this probability is formed by a ratio of a relative accessibility term divided by its integral accessibility equivalent (see the discussion of specification issues related to trip purpose earlier in this chapter for relative and integral accessibility definitions). Huff's use of accessibility measures is particularly interesting for several reasons: 1) It clearly shows how accessibility measures can be practically applied to predicting destination choice. 2) It demonstrates the usefulness of accessibility measures (predominantly used in the public forum) for business and marketing uses. 3) It is one of the methods proposed later in this thesis to address the Navy's facility location problems.

The importance of the Huff model in advancing locational market analysis lies in Huff's description of consumer spatial behavior as a probabilistic phenomenon formed by the ratio of a relative and an integral accessibility terms. This is a rather significant premise, given the number of accessibility measures and combinations of measures available to address locational issues. Academic approaches that were popular prior to introduction of the Huff model, tended "to assume that a consumer, confronted with a choice among several alternative shopping centers, will inexorably choose the nearest center."[64] Generally viewed as the core of these older approaches, Reilly's Law was actually developed to describe the attraction of two competing cities on the population between them rather than on intra-urban retail trade areas. Reilly's hypothesis was that residents

of a region were unavoidably drawn to shopping locations in the one of two competing cities up to a "breaking point" (intermediate point) between the two cities that was in direct proportion to the populations of the two cities and in inverse proportion to the square of the distances from the two cities.[65] This heuristic assumption permitted the delineation of trade areas so that a coverage measure of accessibility could be used for the location of retail facilities.

However, based on empirical studies, Huff found that the attraction to a shopping center is a continuous probability function that decreases with separation[66] where a consumer may by pass the closest shopping center for one that is larger, offers more products and is generally more attractive. "A retail trade area is thus not a fixed line circumscribing a shopping center, but rather a series of zonal probability contours."[67] For clarity, the following expression presents this logical expression:

$$\text{Probability of frequenting a store} \equiv \frac{\text{Relative accessibility to store of interest}}{\text{Integral accessibility to all stores of same type}}$$

Incorporating gravity measures using square feet of retail space as an attraction element and time as an impedance element, Huff's expressed this theory in the following form:

$$p_{ij} = \frac{\dfrac{o_j}{t_{ij}^{\alpha}}}{\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}}$$

where

p_{ij} = probability of a resident from zone i frequenting a store at location j
i = zone of resident location
j = zone of purchases
o_j = size of opportunity or attractiveness of store at j (measured in square feet of retail space)
t_{ij} = travel time from i to j
o_k = size of opportunity or attractiveness of all stores available to consumer i (k = 1 to n)
t_{ik} = distance to all stores available to consumer i (k = 1 to n)
α = parameter reflecting an individual from zone i"s preference for travel to zone j

Based on this hypothesis Dr. Huff then derived a shopping model that predicts the probable sales made at a location j to a person from zone i. The logic of this derivation is presented in the following two expressions:

$$\text{Probable Sales} \equiv (\text{Market demand})(\text{Probability of expenditure})$$

$$\text{Probable Sales} \equiv (\text{Market demand})\left(\frac{\text{Access to store of interest}}{\text{Access to all stores of same type}}\right)$$

Again, by substituting the gravity model terms into the logical expression the probable sales that a store in location j will make from residents of area i can be written as follows:

$$s_{ij} = c_i \frac{\dfrac{o_j}{t_{ij}^{\alpha}}}{\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}}$$

where

s_{ij} = retail expenditures at location j (measured in dollars)

c_i = a measure of market demand for zone i (usually income times the percentage of income spent by the population in i on items sold at j, measured in dollars)

To find the total sales that store j will generate (s_j) rather than just the sales originating from zone i (s_{ij}), the process is repeated successively (i=1 to n) across all zones in the region of j. The Huff model then takes the following form:

$$s_j = \sum_{i=1}^{n} c_i \frac{\dfrac{o_j}{t_{ij}^{\alpha}}}{\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}}$$

An important point, which is often left unaddressed by the notation of this equation, is that the term α is actually distinct for each zone i[68]. Thus it would more correctly be represented as α_i rather than α. The distinction between

different zones is often not made because in application of the equation it is often ignored. This trait of the equation will be discussed in more detail in Chapter 4, but it is also pointed out here, with the introduction of the equation, so that the reader will be aware of the irregularity in notation.

Essentially, the model states that the sales potential of a retail center is directly related to its size. This intuitively follows from the observation that a large center offers a wider range of goods and attracts consumers from a wider area than a smaller center would in the same location. Furthermore, the sales potential of a center is directly related to its proximity to the number and prosperity of its consumers. The larger and closer the number of available consumer shopping dollars, the greater the sales potential. Finally, the model states that the sales potential of a center is related to how exposed it is to competing shopping facilities. The further away other shopping facilities are spatially, the greater the sales potential of a center. Further it "implies that there is no trade area boundary [as previously believed] but a shopping interaction between all zones, though this may fall off sharply with distance."[69]

The Huff model has come to be recognized as a standard for a number of reasons. One of the primary reasons is that comparisons of model produced projections with actual sales data have shown the model to perform quite well.[70] MPSI, a market research firm in Tulsa, Okla., has applied Huff's theories to projecting gas station sales volumes for more than 20 years and found the Huff

model to be accurate witin10% of actual performance.[71] Another is the model's simplicity and conceptual value. As stated by Koening, "If accessibility indicators are going to be used widely in the planning process, they should have a simple structure supporting an empirical justification and making them readily understandable to non-specialists."[72] Accordingly, the Huff model "does not deviate so far from reality as to lack conceptual value even though it may have predictive value."[73] Further model only requires use of two variables attraction in the form of square footage of retail space and impedance measured in distance.

Customized to Navy problem

As was stated in the background section, the issue of concern here is developing facility criteria that fits within the context of the Navy's newly adopted Regional Planning initiative. However, for both practical and theoretical considerations, this issue is addressed by this thesis in a somewhat general form.

Approaching the issue from a broad academic perspective will help create a more comprehensive outline of the role that accessibility measures and their associated issues play in facility location rather than serving merely as a solution to a Navy specific problem. From a practical perspective, much of the Navy's transition to a regional approach deals with specification issues (see Chapter 3) that are likely to change from facility to facility. Criteria that had previously been developed on a base level must now be defined on a regional level. To a large extent the Navy's transition to regional planning is itself a specification issue.

Accurately addressing these issues requires the incorporation of statutory and regulatory requirements. It also requires addressing specifics of the customer base and nature of service for each facility type. Because of the number and variety of facilities and the expertise required to consider specification issues, the facility criteria development methodology is left as a general framework. Additionally, because regional planning is a newly adopted program, details of many specification issues are in flux. Thus, a general framework was used in part because it is supposed that as the Navy implements regional planning, many previously accepted specification constraints will require revisions or, at a minimum, reexamination.

Implicit in the Navy's old approach was a disregard of the spatial distribution of the user population. In addition, the old process ignored the contributions of civilian service provision sources. However, regional planning demands that these factors be considered. As previously stated, the Chief of Naval Operations has directed that planning seek to 1) Partner with neighboring communities to eliminate duplicate functions inside the fence line 2) Privatize, outsource, or civilianize where cost-effective and, 3) Empower individuals to obtain entitlements, benefits, and other QOL expectations on their own.[74] Almost without question, these statements will have profound impacts on how spatial, socio-economic, trip purpose, travel impedance and attractiveness specification issues are accounted for. As a result a need to adopt more comprehensive

measures that can account for the larger collection of specification issues arises from this more thorough consideration of the characteristics of the problem.

The transition to planning for a regional complex of facilities, like those in a metropolitan region, rather than focusing solely on the needs and resources of a single installation (and the required coincident reevaluation of specification issues) closely parallels the shift in the way that markets were viewed as the Huff model came to replace previous thinking. Much like Reilly's Law, which assumed that shopping centers would necessarily draw consumers within their market area, the Navy's previous planning process defined the population to be served by its facilities on a base-by-base basis rather than looking at the region as a whole.

By ignoring several factors, the Navy was able to create facility specific criteria that can be characterized as a ratio of the space per person required for each category of facility. Though it is a gross oversimplification of the P80, this essentially reduced the problem of planning a facility for a base to a problem of one equation and one unknown as shown below.

$$\text{sq. ft. of facility required} \equiv (\text{base population})\underbrace{\left(\frac{\text{sq. ft. required}}{\text{user}}\right)}_{\text{i.e. facility criterion}}$$

In order to derive this equation, a number of assumptions were made. By not being addressed in the equation the most fundamental assumption, that facility location need not even be considered, is well concealed. If location is considered from a regional perspective, it may be that the location that best serves the population is at another base. In assuming the population is that of the base population, the older criterion ignores parts of neighboring base populations, which may be drawn in because of travel or opportunity issues. Lastly, the definition of the criterion ratio itself ignores the contributions of other sources such as civilian provision by assuming exclusive military provision.

Analytic solution not feasible

Evaluating facility criteria from a regional perspective requires that these issues be addressed. Location is a variable, the population to be served is variable, and in the case of civilian provision even the requirement for a facility is a variable. Precluding a singularly optimal analytic solution, the essence of the Navy's regional planning initiative rejects a constrained process in favor of a more flexible approach. In short, there are more variables than the number of equations that can be written. The indeterminate nature of the Navy's problem is largely due to, as the Huff Model suggests, the fact that consumer behavior is a probabilistic rather than quantum function.[75] This, however, does not hinder the Navy's ability to make effective facility related decisions but rather requires the

incorporation of sound qualitative judgments into the analysis of otherwise equal alternatives.[76]

Essentially, regional planning asks the indeterminate question depicted in Figure 1 of the gravity models section of the preceding chapter. Equal accessibility can be provided by a distant location with a large attraction element or by a closer facility with a smaller attractive element. Providing a more specific example, one could ask, "is the population better served by one large fitness center with the most modern equipment and best trained staff available or by closer and smaller gymnasium with less up to date facilities?" Because both options have benefits and costs, there is likely no singularly optimal solution but rather a solution that is preferred given the characteristics of the region. At the conclusion of this thesis a possible follow-on investigation that may lead to a singularly optimal solution will be suggested, but at this point no such solution was identified.

Thus, the aim of regional planning is not advanced by the establishment of rigid criteria but rather is promoted by more appropriately viewing the problem as a balance between competing alternatives. From this perspective, the following section develops a methodology that provides a means to evaluate competing alternatives rather than prescribe a predefined solution. It is an analytic evaluation tool requiring qualitative decisions as opposed to a purely quantitative analysis yielding a definitive solution.

Approach therefore is to simulate

One aspect of specification is selecting which equation appropriately reflects the situation being analyzed. Each of the different accessibility measures discussed (and the numerous derivations not reviewed) has strengths and weaknesses that vary relative to their focus. For this reason, different measures were selected to address different aspects of the Navy's problem individually rather than proposing a one size fits all approach. The following discussion reviews the relationship between each of the selected measures and the issue it was selected to address. A review of how each of the measures can be implemented in a cohesive approach using a Geographic Information System (GIS) is covered in the following chapter.

From an academic perspective, the following discussion provides an example of the types and considerations that would be made as accessibility measures are used in the context of facility location decisions. From a practical perspective of meeting the Navy's challenge, the following discussion shows how each accessibility measure can be specified to the Navy's problem and the section following that will show how the models can be applied in a cohesive framework using GIS. It however, does not represent a detailed solution to the Navy's problem. Should the Navy follow this approach, refinement of specification issues through the incorporation of functional subject matter expertise may very well suggest that other accessibility measures may be more appropriate than those

suggested. In this regard, the following also provides a foundation from which measures outlined in Chapter 2 can be added and deleted as appropriate.

Form of equation

The Navy's location problem is not a singular problem but a balance between the separate issues of maintaining access to services and the business operations issue of optimizing economies of scale. As has been noted, although accessibility measures have been specifically formulated to analyze these types of spatial issues, selection of the most appropriate measure, even for only a singular issue, is a difficult task. In its simplest form, the question is how many facilities are required to provide MWR support, how big should each store be, and in what is the best location for each store. However, the simplicity of the problem is complicated by the dynamic interplay between each of these elements. Thus, a selection of measures has been chosen to address pieces of the Navy's problem as appropriate. However, as has also been pointed out, that task is more one of selecting the most appropriate measure for the problem being analyzed rather than identifying which measure constitutes a singularly superior approach.

Because the essence of the Navy's locational problem is minimizing cost while maximizing service, assuming a business perspective to address the problem has a number of advantages. First of all, applying "state-of-the market business practices"[77] is one of the goals directed by the Chief of Naval

Operations. More importantly, balancing cost and service is what business does. Business seeks to minimize cost while maximizing customer contact. Like the Navy, businesses are also confronted with the indeterminate question depicted by figure 1.

The Huff market location model largely serves as the central model of those selected in this approach. This is because the Huff model was developed specifically to address the balance between cost savings and service maximization that the Navy shares in common with the business community. As will be discussed, the Huff model addresses the geographic separation between supply and demand and can be used for both retail and non-retail MWR operations. Additionally, for retail operations in particular, it can be used to address the impact of civilian provision location on the level of service that the Navy ought to provide.

Accordingly, as a conclusion to the literature review of different models the following review address how different models can be specified to the Navy's specific problem. However, the application of the specified models to analyzing the Navy's problem is reserved for chapter four.

Retail goods or services

In meeting Koenig's requirement that accessibility indicators need to have a simple structure supporting an empirical justification and be readily understandable to a non-specialist,[78] the Huff model asserts that just two

variables, size and travel time, are required to estimate a retail trade areas. As presented earlier in this chapter, the model is based in the following logical expression and has the subsequent analytic form:

$$\text{Probable Sales} \equiv (\text{Market demand})(\text{Probability of expenditure})$$

$$\text{Probable Sales} \equiv (\text{Market demand})\left(\frac{\text{Access to exchange of interest}}{\text{Access to all stores of same type}}\right)$$

$$s_j = \sum_{i=1}^{n} c_i \frac{\dfrac{o_j}{t_{ij}^{\alpha}}}{\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}}$$

A side note of definitions is appropriate at this point. Although the focus of this thesis is on location of MWR facilities and that it is acknowledged that the Navy Exchange does not fall in the MWR organization the term exchange is used in this work interchangeably with MWR retail operation. This is done for several reasons. First the term exchange succinctly differentiates between civilian service or retail operations and military retail operations. This distinction is critical to many of the concepts presented in this work. Secondly, the abbreviated nature of the term exchange facilitates writing conceptual equations, which would otherwise require the term MWR retail operation. Beyond these pragmatic

considerations, the use of the term exchange alludes to the general applicability of the concepts presented here to other Navy organizations beyond that of MWR.

Using the Navy Exchange as an example and specifying the model to the problem of interest would yield the following. The reader should note that in keeping with the objectives of Regional Planning to eliminate duplicate functions inside the fence line and empower individuals to obtain entitlements, benefits, and other QOL expectations on their own[79] as outlined by the Chief of Naval Operations, the term "access to all stores of same type" includes civilian equivalent provision.

$$\text{Probable Exchange sales} \equiv (\text{Military market demand})\left(\frac{\text{Access to store of interest}}{\text{Access to all stores of same type}}\right)$$

$$s_j = \sum_{i=1}^{n} c_i \frac{\dfrac{om_j}{t_{ij}^{\alpha}}}{\displaystyle\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}}$$

where

s_j = retail expenditures at military service provision location j

c_i = total military market available for retail expenditures of population in zone i.
(this could be derived by discounting the total regional military payroll by the average percent of military household income spent on exchange type items)

om_j = size (sq feet) of retail activity opportunity at military service provision location (store) j

t_{ij} = distance measured in time to exchange of study to consumer i (j = 1 to n)

o_k = size (sq feet) of all retail activity opportunities at alternate service provision location k (civilian store or other military stores in region including location of study)

t_{ik} = distance measured in time to all stores available to consumer i (k = 1 to n)

α = constant

Accounts for civilian opportunities

In using the Huff model in this form, analysis would proceed based on successive runs of the model, varying the size and location of retail outlets, until projected regional sales make sense from a business perspective based on the characteristics of the region. Again, the Huff model, having been developed for a business application, is particularly well suited for the locational problem. Incorporating the business operations expertise of the MWR organization, use of the term s_j (which has units of \$) would allow the functional commander to base decisions on revenue projections for each location. Using the Navy exchange as an example of a typical MWR operation, a threshold below which an exchange is not feasible to operate could be employed to determine which exchanges need to be increased in size to attract more revenue or if that is not feasible at certain locations which exchanges should be closed. The context of the region (such as traffic and residential concentration areas) would provide the perspective from which to begin the iterative process. As will be discussed in Chapter 4, the

application section, the regional context will also provide perspective on which operations possibly ought to be operated in a deficit to maintain access to transportation constrained portions of the regional population.

The beauty of applying the Huff model to the Navy's problem is that it doesn't distinguish between civilian opportunities and military opportunities, thus allowing planning to be done in a manner that meets the Chief of Naval Operations mandate to empower individuals to obtain entitlements, benefits, and other QOL expectations on their own.[80] In short, the model allows for better assessment of "all socioeconomic issues that impact development such as population growth, ability of the local work force to support mission, and capability of community infrastructure to support Navy operations"[81] as required by the Chief of Naval Operations.

However, implicit in Huff's assertion that just two variables, retail size and travel time, are required to estimate retail trade areas is that the other innumerable specification issues such as product cost, shopping environment, customer loyalty, proximity to work etc. need not be considered in estimating the retail trade area. It should be noted that the Huff model was developed using civilian retail centers and may not hold true when military retail outlets are incorporated. When specification issues are accounted for, it may be that military retail outlets are in fact significantly different than their civilian counterparts. This concern, though, is somewhat discounted by the fact that civilian retail

outlets would also differ from store to store with respect to these specification issues. Essentially, the very fact that the model says these issues are insignificant to retail market areas suggests that there is no reason to suspect that they would affect the outcome of military market provision. However, the point is raised for verification by subject matter experts in the Navy's retail organization.

Cost savings provides attraction discount factor

One particular specification issue that may impact the results of Huff's model is the cost difference due to tax savings. Because military retail locations are not subject to sales tax, they offer measurable cost savings when compared with their civilian counterparts. Given that the Huff model only accounts for retail location size and travel time, it does not account for the attraction caused by product price variations. However, sales tax is often anecdotally accepted as one of the largest draws to military retail outlets. In regions where there is no sales tax this would not be an issue, but in locations where sales tax is assessed using the Huff model may produce skewed results.

Because the units of this equation are dollars spent it is particularly adaptable to capture the impact of taxes between military morale welfare and recreation facilities and their civilian equivalents. Since the attractiveness of MWR facilities and their civilian equivalents differ only by the cost savings incurred by the military member, the ratio of cost for goods or services purchased

at MWR facilities to civilian equivalents provides a convenient factor by which the benefits of MWR purchases can be increased or their civilian equivalents can be decreased. Therefore when the equation is used, each attraction factor for each military facility can be increased by the prevalent tax rate or the attraction factor for each civilian facility can be divided by the prevalent tax rate. Incorporating these specification considerations into the Huff model it would appear as follows:

$$s_j = \sum_{i=1}^{n} c_i \frac{\dfrac{om_j}{t_{ij}^{\alpha}}}{\displaystyle\sum_{k=1}^{n} \frac{om_k}{t_{ik}^{\alpha}} + \sum_{k=1}^{n} \frac{(1-t)oc_k}{t_{ik}^{\alpha}}}$$

where

s_j = retail expenditures at military service provision location j

c_i = total military market available for retail expenditures of population in zone i. (% of total income)

om_j = size (sq feet) of retail activity opportunity at military service provision location (store) j

om_k = size (sq feet) of retail activity opportunity of all alternate military service provision locations k (including exchange of study)

oc_k = size (sq feet) of retail activity opportunity at alternate civilian service provision location k (store)

t = tax rate; Use reflects additional attractiveness of military provision by reducing civilian provision attractiveness proportionally to tax rate $(1-t)$

t_{ij} = distance measured in time to all stores available to consumer i (k = 1 to n)

t_{ik} = distance measured in time to all stores available to consumer i (k = 1 to n)

α = constant

If detailed data relating the before tax costs is available, this can also be incorporated into the discount rate. In theory, because all operations like the exchange operate on a nonprofit basis there should be a before tax cost savings at MWR facilities. However, it is unlikely that this cost savings could be incorporated into the model for both substantive and pragmatic reasons. From a substantive perspective, this savings is lost by the fact that while a profit margin is not included, some MWR facilities include a surcharge to fund other less profitable MWR activities. This likely offsets most any nonprofit cost savings. From a pragmatic perspective, incorporating these cost savings into the model would require a comparison of an average consumer cost for a good or service from a MWR facility to its civilian counterpart. Capturing these costs would create both large fiscal and administrative costs. Since the Navy would be required to purchase civilian cost survey data and would have to create dedicated data for MWR goods and services it is unlikely that the benefits gained from using this more detailed data will outweigh the costs of collection. Additionally, these data collection cost would be compounded by the fact that this index would require continual recalculation with the fluctuation of the costs of goods or services.

Another specification consideration that may produce skewed results is transportation mode availability. This can be accounted for by performing the Huff model calculation separately for users with access to differing modes of

transportation. Since the constant α weights the impact of the burden of travel for a user, the calculation can be repeated again using a different constant appropriate for a different mode of travel. The following provides an example of how the equation would look if modifications are made for both a tax cost savings and mode of travel specification issues:

$$s_j = \sum_{i=1}^{n} c_i \frac{\dfrac{om_j}{{t_{ij}^{m}}^{\alpha}}}{\displaystyle\sum_{k=1}^{n} \frac{om_k}{{t_{ik}^{m}}^{\alpha}} + \sum_{k=1}^{n} \frac{(1-t)oc_k}{{t_{ik}^{m}}^{\alpha}}} + \sum_{i=1}^{n} c_i \frac{\dfrac{om_j}{{t_{ij}^{m}}^{\beta}}}{\displaystyle\sum_{k=1}^{n} \frac{om_k}{{t_{ik}^{m}}^{\beta}} + \sum_{k=1}^{n} \frac{(1-t)oc_k}{{t_{ik}^{m}}^{\beta}}}$$

where

α = constant for one mode of travel (e.g. private vehicle)
β = constant for second mode of travel (e.g. pedestrian or public transportation)
m = mode of travel

Although the equation begins to look very complex, in actuality it is little more than a repetition of the original equation. Further because use of the Huff model as suggested here is practical only when computed using a GIS, the task of calculating the additional term only requires a second query of the GIS's relational database. Although this should more accurately account for actual travel and purchasing behavior the cost of data collection also increases with each level of disaggregation used. Therefore, in making these and similar

modifications to account for specification issues, the balance between accuracy returns and data collection and computational costs should be closely monitored. As an additional comment, the same process as has been outlined to account for tax saving and travel mode specification issues could be used to modify the model for any other specification issue found to significantly differentiate military service provision from civilian provision.

Entitled goods or services

For entitlements such as gymnasiums, which are free to the service members, the retail model developed above is nonsensical. However, the probability function remains valid. Accordingly, the above model can be used if trips generated rather than dollars spent is used as the values for comparison as shown below:

$$\text{Facility visits} \equiv (\text{Total mil population})\left(\frac{\text{Visits}}{\text{Person}}\right)\left(\frac{\text{Access to facility of interest}}{\text{Access to all facilities of the same type}}\right)$$

$$u_j = \sum_{i=1}^{n} c_i \frac{\dfrac{om_j}{t_{ij}^{\alpha}}}{\displaystyle\sum_{k=1}^{n} \frac{o_k}{t_{ik}^{\alpha}}}$$

where

u_j = number of patrons using the facility at military service provision location j

c_i = total regional military population available patronize the facility j from zone I zone i. (% of total population)

om_j = size (sq feet) of facility at military service provision location (i.e. sq. ft. of gymnasium) j

t_{ij} = distance measured in time from facility of study to consumer i (j = 1 to n)

o_k = size (sq feet) of all facilities available to consumer i (civilian store or other military stores in region including location of study at j)

t_{ik} = distance measured in time to all facilities available to consumer i (k = 1 to n)

α = constant

Thus even though the services offered at the facility have no civilian equivalents, the model still provides a means to evaluate the competition between provision at alternate base locations.

Summary

Maintaining an acceptable level of community support services and maintaining acceptable access to those services in a cost effective manner is a dilemma faced by most all levels of government, both in the military and in the public sector. Although, approaching the problem with different objectives, both accessibility measures and market location analysis, have been developed specifically to address the geographic separation between supply and demand that is central to maintaining access. Accordingly, they provide an informative tool for addressing the locational problem. Most measures of both include both transportation elements and attraction elements. However, embedded in those

two elements are numerous, spatial, socioeconomic, and both travel and attraction measurement specification issues.

Although a substantial amount literature covering both accessibility measures and location theory has been reviewed and an even greater amount has been written, what constitutes the best method is far from clear. Because of the vast amount of variations that can be created by the differing specification issues, identifying a singularly superior approach is a fruitless task. More accurately, the application of these techniques is a task of selecting the most appropriate method for the task at hand and appropriately addressing the associated specification issues in its application. The following chapter seeks to do just that for the locational problem of Navy MWR facilities.

[15] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1175.
[16] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1175-1176.
[17] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1176.
[18] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1176-1177.
[19] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1176. & Koening, J. G, "Indicators of urban accessibility: theory and application," *Transportation* 9 (1980): 146. & Pirie, G. H., "Measuring Accessibility: A Review and Proposal," *Environment and Planning* A 11 (1979): 299.
[20] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1176.
[21] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 13. & Pirie, G. H, "Measuring Accessibility: A Review and Proposal," *Environment and Planning* A 11 (1979): 301.
Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1177.
[22] Guy, C. M., "The assessment of access to local shopping opportunities: a comparison of accessibility measures," *Environment and Planning B: Planning and Design* 10 (1983): 221.
[23] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 20.
[24] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 19. & Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1177.
[25] Pirie, G. H, "Measuring Accessibility: A Review and Proposal," *Environment and Planning* A 11 (1979): 301-302.
[26] Pirie, G. H, "Measuring Accessibility: A Review and Proposal," *Environment and Planning* A 11 (1979): 300.
[27] Voges, E. M., and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators," South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983: 25. & Huff, David L. and John W. Haggerty, *Determination of Intra-Urban Retail Trade Areas*, Los Angeles: Real Estate Research Program, Graduate School of Business Administration, Division , of Research, University of California Los Angeles, 1962, pg 6.
[28] Voges, E. M., and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators," South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983: 25. Pirie, G. H, "Measuring Accessibility: A Review and Proposal," *Environment and Planning* A 11 (1979): 301. Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1177.

[29] Voges, E. M., and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators," South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983: 26. Handy, S. L., and D. A. Niemcicr, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1177. Koening, J. G, "Indicators of urban accessibility: theory and application," *Transportation* 9 (1980): 146.
[30] Wilson, A. G., "A Family of Spatial Interaction Models, and Associated Developments," *Environment and Planning* 3, (1971): 1-32. Voges, E. M., and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators," South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983: 27.
[31] Guy, C. M., "The assessment of access to local shopping opportunities: a comparison of accessibility measures," *Environment and Planning B: Planning and Design* 10 (1983): 222.
[32] Ingram, D. R., "The Concept of Accessibility: A Search for an Operational Form," *Regional Studies* 5 (1971): 106.
[33] Koening, J. G., "Indicators of urban accessibility: theory and application," *Transportation* 9 (1980): 156.
[34] Lakshmanan, T. R. and Walter G Hansen, "A Retail Market Potential Model," *American Institute of Planners Journal* (May 1965): 136. Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1180.
[35] Voges, E. M., and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators," South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983: 26.
[36] Guy, C. M., "The assessment of access to local shopping opportunities: a comparison of accessibility measures," *Environment and Planning B: Planning and Design* 10 (1983): 222.
[37] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 28.
[38] Guy, C. M., "The assessment of access to local shopping opportunities: a comparison of accessibility measures," *Environment and Planning B: Planning and Design* 10 (1983): 222.
[39] Guy, C. M., "The assessment of access to local shopping opportunities: a comparison of accessibility measures," *Environment and Planning B: Planning and Design* 10 (1983): 222. Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 26.
[40] Wilson, A. G., "A Family of Spatial Interaction Models, and Associated Developments," *Environment and Planning* 3, (1971): 4.
Guy, C. M., "The assessment of access to local shopping opportunities: a comparison of accessibility measures," *Environment and Planning B: Planning and Design* 10 (1983): 221.
[41] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 32.
[42] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 7. Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1177.
[43] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 7.

[44] Koening, J. G., "Indicators of urban accessibility: theory and application," *Transportation* 9 (1980): 156. Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 7.
[45] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1178.
[46] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 8.
[47] Koening, J. G., "Indicators of urban accessibility: theory and application," *Transportation* 9 (1980): 153.
[48] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1181.
[49] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1178.
[50] Bach, L., "The Problem of Aggregation and Distance for Analyses of Accessibility and Access Opportunity in Location-allocation Models," *Environment and Planning* A 13 (1981): 959.
[51] Voges, E. M., and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators," South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983: 4.
[52] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1178.
[53] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1178.
[54] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1178.
[55] Hanson, S. and M. Schwab. "Accessibility and interurban travel." *Environment and Planning A* 19 (1987): 738. Kitamura, Ryuichi and M. Kermansha, "Sequential models of interdependent activity and destination choice," *Transportation Research Record* number 987 (1984): 86.
[56] Ingram, D. R., "The Concept of Accessibility: A Search for an Operational Form," *Regional Studies* 5 (1971): 101. Voges, E. M., and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators," South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983: 7.
[57] Ingram, D. R., "The Concept of Accessibility: A Search for an Operational Form," *Regional Studies* 5 (1971): 101. Voges, E. M., and A. H. Naudé, "Accessibility in Urban Areas: An Overview of Different Indicators," South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983: 7.
[58] Morris, J. M., P. L. Dumble and M. R. Wigan, "Accessibility indicators for transportation planning," *Transportation Research A* 13 (1979): 94.
[59] Morris, J. M., P. L. Dumble and M. R. Wigan, "Accessibility indicators for transportation planning," *Transportation Research A* 13 (1979): 95.
[60] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1179
[61] Morris, J. M., P. L. Dumble and M. R. Wigan, "Accessibility indicators for transportation planning," *Transportation Research A* 13 (1979): 96.
[62] Handy, S. L., and D. A. Niemeier, "Measuring Accessibility: An Exploration of Issues and Alternatives," *Environment and Planning* A 29 (1997): 1179

[63] Wilson, A. G., "A Family of Spatial Interaction Models, and Associated Developments," *Environment and Planning* 3, (1971): 4.
[64] Lakshmanan, T. R. and Walter G Hansen, "A Retail Market Potential Model," *American Institute of Planners Journal* (May 1965): 135.
[65] Reilly, William J, *The Law of Retail Gravitation*, New York: Pilsbury Publishers, 1953, 8.
[66] Lakshmanan, T. R. and Walter G Hansen, "A Retail Market Potential Model," *American Institute of Planners Journal* (May 1965): 135.
[67] Huff, David L. and John W. Haggerty, *Determination of Intra-Urban Retail Trade Areas*, Los Angeles: Real Estate Research Program, Graduate School of Business Administration, Division of Research, University of California Los Angeles, 1962, 5.
[68] Huff, David L. and John W. Haggerty, *Determination of Intra-Urban Retail Trade Areas*, Los Angeles: Real Estate Research Program, Graduate School of Business Administration, Division of Research, University of California Los Angeles, 1962, 27-28.
[69] Lakshmanan, T. R. and Walter G Hansen, "A Retail Market Potential Model," *American Institute of Planners Journal* (May 1965): 136.
[70] Lakshmanan, T. R. and Walter G Hansen, "A Retail Market Potential Model," *American Institute of Planners Journal* (May 1965): 136. Huff, David L. and John W. Haggerty, *Determination of Intra-Urban Retail Trade Areas*, Los Angeles: Real Estate Research Program, Graduate School of Business Administration, Division of Research, University of California Los Angeles, 1962, 4.
[71] Daniel, Larry, "Enhanced modeling helps position business geographics in the retail industry," *Business Geographics Volume 1, Number 5* (September/October 1993): 39.
[72] Koening, J. G. "Indicators of urban accessibility: theory and application." *Transportation* 9 (1980): 153.
[73] Huff, David L. and John W. Haggerty, *Determination of Intra-Urban Retail Trade Areas*, Los Angeles: Real Estate Research Program, Graduate School of Business Administration, Division of Research, University of California Los Angeles, 1962, 14.
[74] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 18.
[75] Reid, Hal, "Defining trade areas or trying to see the invisible," *Business Geographics Volume 3, Number 3* (March 1995): 46.
[76] Edward J. Kaiser, David R Godschalk and F. Stuart Chapin, Jr. *Urban Land Use Planning; Fourth Edition* (Urbana and Chicago Illinois: University of Illinois Press, 1995), 255.
[77] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 3.
[78] Koening, J. G. "Indicators of urban accessibility: theory and application." *Transportation* 9 (1980): 153.
[79] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 18.
[80] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 18.
[81] U. S. Department of the Navy. Naval Facilities Engineering Command. *Shore Facilities Planning Manual: A System for Planning of Shore Facilities, NAVFACINST 11010.44E.* 15 December 1987, II-6.

Chapter 4: Application: Using GIS for locational analysis

Having established a general familiarity with different models along with their associated specification issues and having reviewed how those models might apply to the Navy's problem, what remains is to bring the two together into a cohesive process for analysis. Geographic Information Systems (GIS) are specifically designed to meet this type of task.

The models presented provide insightful information into the nature of locational decisions. Yet, despite "enhanced data availability and quality, there is minimal incorporation of the methodological advances in spatial analysis of the 1960s and 1970s."[82] The advent of desktop computing and the development of desktop-based GIS are reversing that trend. At the end of the 1970s, GIS were not central to geographically-related research, but at the beginning of the 1990s, GIS represented a significant and growing field.[83] This is because of the competitive advantage and business effectiveness marketers gained from being able to handle geographical data efficiently. As with the application of the Huff market model to the Navy's MWR challenge, these same advantages are applicable to the public sector. This can be seen by its use in countless applications including the location of health care facilities,[84] retail location analysis,[85] chain restaurant location analysis[86] and San Diego's regional government facility analysis.[87]

In an era where desktop computing is common, the sheer number of calculations needed to calculate even a simple gravity measure of accessibility for a single location (one for residential zone or each individual depending on the chosen level of disaggregation) suggests the need for automated calculation. It could even be said that use of complex models like the Huff model are only made practicable with the use of computers. However, both accessibility and location theory are not purely arithmetic concepts but also contain spatial elements. GIS systems provide a dedicated software platform that can address both the arithmetic element and spatial element of geographic problems.

Thematic mapping: Accessibility insights & problem comprehension

One of the strengths of GIS beyond arithmetic computations is its ability to organize data for analysis. Though it seems intuitive that data must be organized before analysis, spatial data must also be structured before it can be analyzed for trends or spatial patterns. If for no other reason, this provides the analyst an opportunity to understand the problem before it is solved. GIS provide a platform to accomplish this task.

Entering data into a GIS system not only prepares the data for spatial analysis (using techniques like the Huff model) but also provides the capability to analyze the data using thematic mapping. By segregating data into different categories (referred to as themes or layers in GIS terminology) the analyst can

remove or add layers at will to help recognize spatial patterns of information in much the same manner that spreadsheets and presentation graphics help the viewer to discern tabular or visual patterns of information.[88] GIS have the additional benefit of allowing the analyst to make simple spatial cross-references and queries that can substantiate or refute visual observations of spatial patterns. For example, with regard to the Navy's facility location problem, the analyst will want to understand the proximity of military MWR locations to comparable locations in the community or proximity to highly trafficked areas.

Origin-Destination trips v. trip chains

Thematic maps also provide the opportunity to identify the appropriateness of heuristic assumptions. Accessibility might be more a function of consolidation of service provision points into a singular area where you can get everything done,[89] rather than residential proximity. The measures reviewed earlier assume a single trip from residence to store and back for each store trip. In reality trips are often chained from one destination to another. A consumer may journey to the store on his or her way home in the afternoon rather than make a devoted trip. The validity of this notion can be anecdotally demonstrated by the popularity of stores such as Super Wal Marts where the consumer can make one stop for both grocery and household needs. Similarly the military member's accessibility wouldn't be served by running from one base to go to the exchange and to another base to go to the commissary. In light of this the analyst should

keenly seek opportunities to locate near service and facility concentration areas so that more efficient trips can be made. The more sprawling the area more important facility concentration is.[90]

Mode availability

Thematic maps also provide an insightful way to evaluate accessibility issues related to the mode of travel. Again service and facility concentration areas provide a means to address this problem. For example collocating facilities where those restricted to pedestrian access may already be traveling would improved their accessibility even as direct accessibility falls off. And even more obviously locating goods or service provision points close to the residences of pedestrian-restricted populations acts to maintain access levels. If the data is entered into a GIS using disaggregated themes, thematic maps allow the analyst to visualize spatial patterns between clusters of different groups of data points. For example, the proximity, or lack thereof, between pedestrian-constrained residential groups and shopping facilities may appear as a significant issue.

Thematic mapping: a part of the whole

While thematic mapping is especially useful in illuminating the nature of the problem being analyzed (and may even provide conclusions) it is but one of the strengths of GIS. Nonetheless, because data needs to be entered into a GIS before it can be analyzed, thematic mapping is a convenient tool that helps in identifying what spatial analysis model (be it an accessibility measure, a location

theory measure or some other measure) is appropriate for the problem being analyzed. Additionally, as noted earlier, it helps identify which specification issues need to be addressed. However, because the appropriate accessibility measure is determined by the problem it is being applied to, thematic mapping will not by itself specify which measure is appropriate. This task can only be done by matching the strengths of different accessibility measures with the issues identified by thematic mapping.

Methods operationalized

Having reviewed some of the individual capabilities of GIS that together form a comprehensive tool for analyzing spatial issues, the following discussion focuses on how each of the components could be sequenced when applied to locational decisions. Accordingly, by example, the following discussion outlines how GIS can be used to both identify appropriate measures and how to apply these measures once they are identified. For the purposes of the Navy, however, the following provides a feasible approach to its MWR facility location problem. As was pointed out earlier, because of the number and variety of MWR facilities and the expertise required to consider the associated specification issues, this approach only represents a general framework and not a complete process. It is a fairly specific in its focus on the issues faced by the Navy, but a general framework nonetheless. This process is as much an art as it is a science and can vary from situation to situation. Additionally, the process is rather lengthy and

involves numerous intermediate steps. For this reason figure 2 is provided to help illustrate the process proposed in this work for the Navy's location problem.

Figure 2: Locational Analysis Operationalized

Step 1: Assemble GIS data

1) Collect regional data
    - Local data
        - Local land use
        - Local zoning
        - Regional road network
        - Others as appropriate
    - Military base locations
    - Military residential locations
    - Facility locations for each service to be analyzed
        - Military
        - Civilian
2) Load GIS with data sets
    a) Load each type of data as a separate category (theme or layer in GIS terminology)
    b) Insure theme type is appropriate for type of data being entered (point, line or polygon)

Step 2: Qualitative analysis

1. Evaluate region for areas of service member residential concentrations
2. Evaluate region for high use concentration areas
3. Evaluate residential location proximity to military installation areas & concentration areas

Step 3: Spatial analysis using location theory

1. Analyze region for acceptable levels of coverage
    a. Determine coverage distance
    b. Plot coverage and analyze for redundancies
2. Spatial analysis using location theory
    a. Calculate travel terms using a GIS spatial analyst
    b. Calibrate model
    c. Assume initial configuration of facility locations and sizes
    d. Calculate projected sales for each location
    e. Evaluate projects and modify assumed configuration of facility locations and sizes
    f. Repeat successively until regional configuration of locations and sizes that generates highest amount of revenue, and does not violate any business operations constrains or deny access to any portion of the population, is obtained

Step 1: Data collection and assembly

The first step is to map the problem. The significance or magnitude of this step cannot be understated. Although there are numerous ways to classify different levels of planning,[91] none of the more advanced planning functions such as strategic planning, tactical planning, operational planning or project planning,[92] can be achieved without inventorying the environment in which planning is to be done. Employing GIS, the intelligence gathering function of planning is largely done by collecting the required information and geocoding it (spatially referencing the data to a specific location).

For organizational efficiency it is recommended that each of these data sets (or themes, in GIS terminology) be created separately. Since the methods for doing this vary between the different GIS software packages available, the details of how these data sets would be created are only reviewed in general terms. Moreover, data will be available in many different formats. Obviously, data entry requirements will vary with each format that the data is collected in. However, it is worth noting that as GIS becomes more and more prevalent, data is becoming increasingly available in GIS format, which immeasurably facilitates data collection.

Regional data

In analyzing a regional network of military installations the foundation of the analysis will rest on how the database is developed. This will provide the

framework to which all other data will be referenced. For the Navy facility location problem this will most likely consist of regional data sets including roads, local land use zoning and building themes. The primary source for this data would be local municipal planning agencies. Additionally, the US Census Bureau publishes the Topologically Integrated Geographic Encoding and Referencing system TIGER files, which are available for download at http://www.census.gov/geo/www/tiger/index.html. Though much of the census data provided by the TIGER files will not be required for the Navy's analysis, they provide an excellent source of information regarding the context of the region in which the Navy is planning.

In constructing the regional database file the road network theme requires special attention for several reasons. First, street addresses are the most common form of referencing points within a region. This is true for residential locations and for military and civilian service provision locations. The road network also almost exclusively defines the connection between points within a region. Whether measured in time or distance the impedance element of all the models reviewed is generally measured along a road network, regardless of the mode of travel. Accordingly, in building the road network care should be given to data collection and creation to insure that it can be used as a means of spatial reference.

Problem-specific data

In addition to collecting regional information the Navy will also have to collect information specifically related to their locational problem. This will largely entail collecting data about base locations, residential locations of the military population to be served, and data about the location of each facility type to be analyzed and the location of their civilian equivalents.

When entering data into the GIS, polygons the size and shape of the base fence line in which facilities can be located will likely be the most useful for a base location theme. However, if more sophisticated data sets have already been created, a combination of a line theme representing streets on the base and a polygon theme representing buildings on the base would better serve this purpose.

The base housing office would be the likely source for the information required to create the residential location theme. The data provided by the base housing office will, however, need to be geo-referenced to its location in the region. Particularly, if the data is obtained from the housing office in an electronic format such as a spreadsheet or relational database, GIS has the capability to import the data directly. This is done by importing the address information in a tabular format and creating a point theme containing a data point at each location on the street network, obtained from the local planning agency or US Census Bureau. However, the residential theme created by importing the table will need to be verified for any geocoding errors that may occur.

The mere creation of this theme highlights the power of GIS for spatial data analysis. In much the same manner as a relational database allows the recording of several attributes of data item, a GIS allows the recording of several attributes for a spatial location. For the residential location theme attributes such as family size and military rank will provide additional insights above that which could be gained from a mere street address.

The spatial nature of the Huff model further highlights the need for attributes. In creating facility location themes it is suggested that a theme for each facility type would need to be created and the opportunity size (size of the activity in square feet) required by the Huff model would be recorded as an attribute of each location. Commercially available "yellow-page" databases with establishments categorized by US Census Bureau Standard Industrial Code (SIC) provide a convenient source for civilian equivalents. Because the data is categorized by SIC, finding a SIC common to the facility being analyzed will provide an adequate regional listing of civilian equivalent provision locations.

Building size for civilian service provision locations can come from a number of sources such as local tax records (which many municipalities make available on via the internet), from local planning agencies' land use records (which are often already recorded in GIS polygon format). In addition the data can be created using aerial photos available from local or state data planning agencies, or the U.S. Geological Survey at http://www.usgs.gov/. Additionally,

the proprietor of each facility, be it a civilian company or the military, is another specification feature that can be recorded as an attribute.

Alternate data and possible sources

Because the Huff model will later be offered as a key element to analyzing the Navy's loctional problem, the data required for that model and possible sources for that data have been the focus of the discussion thus far. The following section will review some other relevant characteristics that ought to be examined but no definitive guide to what data should be collected can be given. The relevant data types are as numerous as the types of facilities being analyzed and the characteristics of the region. Accordingly, some possible sources of data relevant to the locational problem are suggested in Tables 4 through 6.

Table 4: Internet GIS Data Sources

Starting the Hunt

- http://www.cast.uark.edu/local/hunt/index.html
- excellent index to GIS data sources by Stephen Pollard, sponsored by the Center for Advanced Spatial Technologies, the University of Arkansas

The GIS Data Depot

- http://www.gisdatadepot.com/
- Excellent data repository for both the U. S. and other countries - much of the data is free for download, some available only for purchase. Good place to get Digital Chart of the World data by country

USGS Node of National Geospatial Data Clearinghouse

- http://nsdi.usgs.gov/

CIESIN Center for Earth Science Information Network, Columbia University

- http://www.ciesin.org/
- Very good site for downloading data

RPM Information Network GIS

- http://home.earthlink.net/~rpminfonet/gis.html
- Nice links to data sources, including a more user-friendly link to CIESIN's census data archives, plus other interesting GIS links

Geospatial Datasets

- http://www.utexas.edu/depts/grg/virtdept/resources/data/data.htm
- List maintained by the Department of Geography, the University of Colorado at Boulder

ArcData Online

- http://www.esri.com/data/online/index.html
- GIS data sets from ESRI (the makers of ArcView, which is one of the most popular GIS packages available.

Source: GIS and other Data Sets Online http://mather.ar.utexas.edu/Planning/data/index.html

Table 5: Statistical Data Download Sites

Statistical Resources on the Web
- http://www.lib.umich.edu/libhome/Documents.center/stats.html
- Excellent starting point for searching all kinds of statistics

Stat-USA
- http://www.stat-usa.gov/
- Business and economic information from the US government

U. S. Demography Home Page
- http://www.ciesin.org/datasets/us-demog/us-demog-home.html
- From CIESIN - Consortium for International Earth Science Information Network

U.S. Bureau of the Census
- http://www.census.gov/

U.S. Bureau of the Census - Data Access Tools
- http://www.census.gov/main/www/access.html

U.S. Bureau of the Census - 1990 Census Lookup Site
- http://venus.census.gov/cdrom/lookup

U. S. Bureau of Transportation Statistics
- http://www.bts.gov/
- U. S. Department of Transportation - see also the TRIS Online (http://tris.amti.com/sundev/search.cfm), the largest database of published transportation research on the internet

Right to Know Network
- http://www.rtk.net/

Social Sciences Data Collection, U.C. San Diego
- http://ssdc.ucsd.edu/

Bureau of Economic Analysis – U. S. Department of Commerce
- http://www.bea.doc.gov/

Source: GIS and other Data Sets Online http://mather.ar.utexas.edu/Planning/data/index.html

Table 6: Transportation Data Sites and Links

Urban Transportation Research Links
- http://mather.ar.utexas.edu/cadlab/handyweb/UTPLinks.html
- Maintained by Dr. Susan Handy, UT Austin Community and Regional Planning Program

Highways and Communities Research Links
- http://mather.ar.utexas.edu/cadlab/handyweb/HwyLinks.html
- Maintained by Dr. Susan Handy, UT Austin Community and Regional Planning Program

Source: GIS and other Data Sets Online http://mather.ar.utexas.edu/Planning/data/index.html

Step 2: Qualitative analysis

Having organized the data, it is now ready for analysis and query. A qualitative understanding of the region's characteristics is the first step of analysis. The data manipulation capabilities of GIS are especially useful for this segment of the analysis. By displaying different themes relative to each other the regional characteristics that may foster or detract from accessibility can be identified.

As discussed in Chapter 3, even using the most appropriate accessibility models, the Navy's facility location problem precludes a singularly optimal solution. However, by incorporating factual based qualitative judgments a preferred option, given the characteristics of a region, can be identified. Thus, insights from a qualitative review of the problem not only provide valuable information for making a final decision between competing alternatives, but also provide a starting point from which alternatives can be developed.

Evaluate region for areas of service member residential concentrations

One of the primary characteristics to look for would be military residential concentration areas. This would consist of residents of the entire regional military population including those living off base, those living on base, and those living in the barracks. (Note the distinction between each of these should be recorded as attributes so that they can be segregated if required.) High residential concentration areas suggest areas where facilities should be located close by.

Transportation mode availability is a primary consideration when considering residential concentration areas. Residential areas with high populations that don't have access to a personal vehicle for transportation would require special consideration in the facility location scheme. Accordingly, entering vehicle ownership data available from base security, as an attribute of the residential locations theme, would provide a means to identify where those populations are located. Additionally, with this data, mode considerations could be further disaggregated for patterns among single car families. By default, if one car sits at a place of work all day the remainder of the family becomes pedestrian or public transit constrained. Minus this data the analyst would be left to rely on anecdotally accepted notions, like the belief that only young sailors living in the barracks don't have cars, to identify pedestrian constrained populations.

Evaluate region for high use concentration areas

Overlaying the road network, the local building file and the facility type themes including civilian service provision points would provide a means of identifying service concentration areas. In reviewing the region for high concentration areas the analyst is not looking for a clustering of the facility of interest but rather areas of high traffic where people are likely to already have a need to go. This could be the intersection of two major highways, the location of a regional shopping mall or the central business district of an area. Essentially the analyst is looking for where people already are. In providing trip-chaining opportunities locating facilities as close as possible to these areas increases the users' accessibility. Further, all of the accessibility measures reviewed are based on home to destination trips and thus neglect the value of trip-chaining in increasing accessibility. Thus, when choosing between two alternatives with equal accessibility, the one closer to high concentration area is clearly be preferred.

Evaluate residential location proximity to military installation areas & concentration areas

A somewhat obvious but noteworthy point is that location options near residential concentration areas and high use areas would compound the users' facility access. Thus, bases close to both offer prime locations for facility sighting.

Step 3: Spatial analysis using Location theory

Although spatial analysis can be done by hand, GIS automates much of the process, thus reducing calculation effort and errors. The following review of how a spatial analysis might progress is only discussed at a conceptual level for several reasons: 1) The details of how a spatial analysis is performed vary from software platform to software platform. 2) Should the Navy choose to use this method, the details of a spatial analysis will vary depending on the specification assumptions deemed appropriate given the actual provision requirements (statutory, regulatory, operational, perceived, etc.). 3) The analysis will vary depending on the characteristics of each region it is used in, and 4) the dedicated software options that automate the process (which will be offered as an alternative to doing a full spatial analysis) are available. Central to all of these issues however, is the fact that the Navy has not progressed with its Regional Planning initiative beyond a policy level, which makes identifying a specific analysis approach difficult.

Step 3.1: Analyze region for acceptable levels of coverage

Although much discussion has been given to the Huff model establishing its relevance to the Navy's problem, a simple coverage model of accessibility is offered as a first stage for analysis. This is done for a couple of reasons. First there is no reason to use more complex measures if simple measures will suffice. It may be that using a coverage model will provide sufficient insight into the

nature of the regional facilities network to meet the needs of the Navy. In being a simpler form, the value of a coverage analysis lies in it's being more understandable to non-specialists. Secondly, even if coverage is not sufficient to fully illuminate what is the preferred alternative among competing alternative facility locations and sizes, it is likely that one or more locations will be redundant and thus can be eliminated from the number of choices the analyst must consider. Because coverage models define access using a coverage radius or disc, which may or may not overlap with others, they are particularly well suited to identify redundant provision.

As discussed in Chapter three, given a regional network of bases the locational decision is only constrained by the location of bases in the region. Thus, the locational choice can vary from provision at one base to provision at all bases to anything in between. Likewise attractiveness, which is measured by the area of a facility, can range from the size required to support the entire regional population if only one provision point is used to the minimum size required to justify operating a facility. Therefore, even when only two variables of the location question are considered, the locational question provides an infinite number of possibilities. Accordingly the regional analysis is greatly advanced if one or more locations can be removed from the infinite number of possibilities by the use of coverage measures.

Setting the coverage radius: distance as a function of residential choice

Coverage models seek to maximize the number of people that have access to a facility within a given distance.[93] Accordingly, the coverage game is to center coverage discs so that a maximum of the population is covered. But before discs can be drawn, the appropriate size of the disc must be selected. Since a service member's residential choice constitutes a measure of the military member's preference for access to the base and base-related facilities, an average distance between the residential locations of military and their place of work is suggested as an appropriate cut-off distance. Having georeferenced residential locations onto a street network calculating the average distance between residential locations and the place of work is a relatively simple task of using a network analyst feature of GIS to determine the distance for each residence and then dividing by the number of residences. This would be expressed in the following form:

$$C_f \equiv c\left(\frac{\sum_{i=1}^{n} D_{i_w}}{n}\right)$$

where

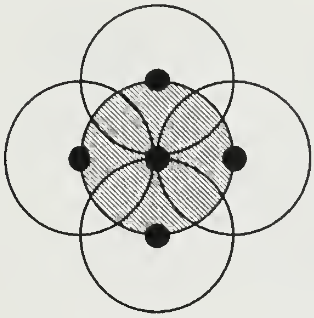
C_f = cut-off distance for facility of study
D_{i_w} = distance to work for ith individual
n = number of individuals in the regional population
c = proportionality constant selected by functional commander

Incorporating a proportionality constant c in the definition of the cut-off distance allows for managerial input into what portion of the average travel to work constitutes a reasonable distance for access to service provision facilities. For example if an exchange was to be studied, a functional commander could determine that it is reasonable to travel 1.5 times the distance to an exchange as it is to travel to work.

Plot military service coverage

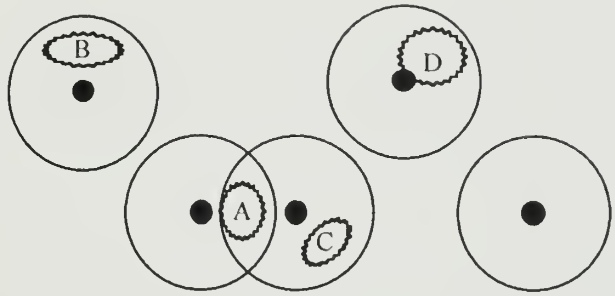
Having selected a cut-off distance, the next step would be to analyze the region for redundant coverages. Figure 3 provides a representation of how this is done. The analyst would plot coverage circles centered at each point of service provision of radius C_f. Provision locations like those noted by the hatched circle in Figure 3, which are completely covered by other points of service provision, could then easily be identified as redundant. Care however, should be taken to ensure that this measure is only used for facility types that are non-essential, as the center circle would not actually be covered by other bases for those facility patrons without access to transportation.

Figure 3: Redundant Military Provision



Likewise, coverage discs could be used to identify redundant provision, by comparing coverage areas with residential locations, if the region happens to have neatly pocketed concentrations of military residences as indicated by A through D in Figure 4. Since all residential locations A through D are covered by three points of provision the remaining two could be eliminated as provision points. If a civilian equivalent was deemed to be equal in all respects a coverage circle could also be drawn for the civilian equivalent as well. For example, in Figure 3 the circle covering residential concentration B might actually be centered on a Wal-Mart rather than being centered on an exchange.

Figure 4: Redundant Military Provision



Depending on the facility type this analysis may not need to proceed any further. If the facility of study has no civilian equivalents and is considered an entitlement a coverage area analysis of service provision might be all that is needed to ensure that the population has facility access. However, depending on the importance of the facility, the analysis could proceed on to the next recommended phase (spatial analysis) to identify the proper size of facility at each location.

Step 3.2: Apply Huff model

Having eliminated all the redundant military coverage areas identified by the coverage model, the smaller set of provision locations can be further analyzed for additional redundancies created by civilian provision as well as to ascertain the appropriate size of a facility. Because the Huff model includes an attraction term that is excluded from the coverage model it provides an appropriate measure for this level of analysis. First, a probable set of facilities is assumed from the provision locations remaining from the coverage analysis. This first iteration of

locations or alternatives is further specified relative to size estimates using qualitative information such as proximity to traffic concentration areas, proximity to residences and proximity to other similar businccss. For example, a base closely situated to a Wal-Mart (or other exchange) would likely only require a small exchange, while one remotely located from similar businesses but near a large concentration of military population would require a large exchange.

Assume beginning composition of locations and sizes

As alluded to, this is an iterative process. Analysis proceeds based on successive runs of the model until projected regional sales make sense from a business perspective based on the characteristics of the region. Again, the context of the region (such as traffic and residential concentration areas) would provide the perspective from which this judgment is made and a starting point for the iterations.

It is crucial that information gained from the qualitative assessment be used as the foundation for any decisions based on the Huff model. Although, the Huff model is particularly well suited to evaluate the balance between attraction and impedance elements, of competing alternatives, it can mask the accessibility impact to facility users, because it measures revenue generated. This is particularly true for portions of the population that may have unique constraints. For example, while a very attractive store that is very far away may be equally or

more appealing, to users with access to an automobile, this would likely not be the case for a pedestrian constrained part of the population.

Model calculations

Either the original Huff model, the Huff model modified for tax considerations or the Huff model modified for tax savings and mode considerations could be used in performing the spatial analysis. The original Huff model will be discussed here, as the modified forms essentially follow the same process. For reference the original Huff model is restated as follows:

$$s_j = \sum_{i=1}^{n} c_i \frac{\dfrac{om_j}{t_{ij}^{\alpha}}}{\displaystyle\sum_{k=1}^{n} \frac{o_k}{t_{ik}^{\alpha}}}$$

Traditionally, in performing a spatial analysis using the Huff model, the analysis breaks the region into geographic sub-areas representing the point locations for demand (the i elements). However, since the Navy's location problem deals with a sub set of the population at large, it is offered that individual military residences rather than residential zones be used for the i terms.

Again, the feasibility of doing a spatial market analysis is only made practical with the use of a GIS. The opportunity terms (om and o) of the equation represent a relatively small data set that is only as large as the number of

facilities in the region of the type being analyzed. However, the impedance terms (t_{ij} and t_{ik}) require a lengthier calculation. Most GIS platforms have a module or extension as part of the program (although sometimes the extension is required to be purchased separately)[94] that can calculate travel times between two points on a road network. Having collected the road network data from a local planning agency, the U.S. Census Bureau TIGER files ,or other source, calculation of travel times becomes merely a GIS query similar to a relational database query.

Although the use of a network analyst feature of a GIS makes measuring travel impedance in terms of time a relatively simple calculation, a straight-line distance is often used as an impedance measure for added simplicity. Although some researchers posit, "the type of distance measure does not influence the optimal location pattern of a system of infrastructural facilities",[95] this is generally accepted to only be true when the transportation network is relatively uniform. The problem with straight-line measures becomes intuitively obvious when characteristics such as rivers, tunnels and one-way streets that would increase travel time are considered.

Model calibration

Having just calculated the travel times t_{ij} and t_{ik} using a network analyst feature of a GIS and given that o_j and o_k were obtained as part of the regional dataset collection, c_i and α must be determined to use the model. The first step

is to calibrate α using patronage data. Sample counts of store patronage for the facility of interest will need to be collected. Then the constant α can be calibrated using the probability function on which Huff's model is based.

$$p_{ij} = \frac{\dfrac{o_j}{t_{ij}^{\alpha}}}{\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}}$$

Given that p_{ij} is the probability that a customer i (or if using the traditional sub-zone approach, a customer from zone i) will frequent a store, the summation of all consumers will equal the proportional probability that the population will frequent the store of study. That probability ratio times the total regional population should equal the number of customers that the store receives and can be expressed as follows:

$$E_j = n\sum_{i=1}^{n} \frac{\dfrac{o_j}{t_{ij}^{\alpha}}}{\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}}$$

where

E_j = the number of expected customers to patronize the store at j

Since all terms except α are known, all that remains solve for α. Because an algebraic solution would be "extremely difficult", Huff suggest using an iterative approximation to determine α. The sequences of steps, suggested by Huff[96], for this approximation are as follows:

1. Assume a particular value for α which is greater than unity. Correspondingly, input the other terms (impedance and opportunity), which have been previously calculated and calculate the expected patronage.

2. Compare the expected probabilities with the actual relative frequencies obtained from the survey data and calculate a correlation coefficient.

3. Continue to substitute incremental values for α until the highest correlation coefficient is obtained. This will represent the optimum value of the parameter α.

Huff presents a flow chart[97] for a program that could be written to accomplish this task. However, given that his original presentation of the Huff model was published in 1962, more current dedicated software packages could be used to perform this task. Because the process will vary between different software packages this process is not detailed here. Furthermore, as will be suggested alternatives are available to avoid calibration entirely.

Although not directly addressed since the original presentation of the Huff model in Chapter 3, the term α is actually distinct for each zone i. However, because the military residential location data set constitutes a complete

enumeration of the population the model can be run as if the entire population were a single zone, thus removing the need to calculate distinct α terms for each zone. This however, makes the iterative calculation somewhat more difficult by requiring that the model be summed for each individual ($\sum_{i=1}^{n}$). In doing this more accurate results should be gained by disaggregating the population to the individual level. However, variations in α across different segments (neighborhoods) in the region will be lost by assuming a single α term.

The variations in α could be accounted for by using the model on a zonal basis as originally proposed by Huff. If a zonal model were to be used the calibration equation would have the following form.

$$E_{ij} = P_{ij} * C_{ij} = \frac{\dfrac{o_j}{t_{ij}^{\alpha}}}{\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}} * C_{ij}$$

where

E_{ij} = the number of customers from zone i expected to patronize the store at j
C_{ij} = the number of customers from zone i available to patronize the store at j

In this form a separate α term would be calibrated for each zone i using the same methods outlined above. The model would then have to be used on the zonal level, thus eliminating any accuracy gains obtained from using data

disaggregated to each individual. However, the variations in α across different zones would only be significant if the zones were segregated enough that residents in each zone displayed a common travel propensity for the types of items sold at the store that is being analyzed that is distinct from those of the other zones.

Generally α is calculated on a regional basis and variations among neighborhoods are not accounted for. For this reason using a single regional α term has the added benefit of possibly eliminating the need to calculate α entirely. Gravity model's like those on which the Huff probability ratio is based are often used by regional planning organizations. If a region that the Navy is analyzing is covered by a regional or metropolitan area planning organization the α term might very well be obtained from that organization.

The remaining term of the Huff model that has not yet been determined is the measure of market demand c_i. As noted earlier for retail locations the most productive measure of market demand would likely be the proportion of income spent by patrons on the items sold at the store of interest. This could be obtained by surveying patrons at the store of interest. Again as noted earlier the proposed measure of demand for non-retail operations, like gymnasiums would be the number of visits made by the patrons of the facility of interest. Here again, this could be obtained by surveying customers at the facility of interest or more

accurately by simply counting the number of patrons that frequent the facility of interest.

The use of actual patron visit counts highlights an alternative and possibly more accurate means of determining c_i for retail locations. Since all terms of the Huff model are known (including α, which has been calibrated) c_i could be calibrated (using the same iterative process that was used to calibrate α) by using actual sales data at the store of interest rather than customer survey. Given that it is unlikely that customers will know with any degree of certainty what portion of their income is allocated to the types of goods sold at the store being analyzed, calibration offers a possibly more accurate means of obtaining c_i. Here the equation projecting sales revenue shown below would be used for calibration as opposed to the equation projecting the number of visits that was used to calibrate α.

$$s_j = \sum_{i=1}^{n} c_i \frac{\dfrac{om_j}{t_{ij}^{\alpha}}}{\sum_{k=1}^{n} \dfrac{o_k}{t_{ik}^{\alpha}}}$$

As the reader will likely have discerned, model calibration is quite possibly the most difficult part of using a model. Obtaining calibration terms from regional planning organizations provides an option that should eliminate the

need for calibration. Furthermore, because the local planning organization would have likely generated the terms using a large regional sample the terms are likely to be more accurate than those that could be generated using the smaller Navy data set. However, applying calibration terms generated using aggregate regional data to the Navy's relatively disaggregate population may not be appropriate.

An alternative means to avoiding the calibration dilemma is offered by dedicated software packages that automate the calibration process. Moreover, these packages offer other benefits such as bundled data sets and automation of other arduous aspects of using accessibility and location models. Some dedicated software options are discussed in the next section.

Ready-made software solutions

Although, the Huff model uses only two specification terms and is therefore considered a relatively simple model for market area analysis, it would be hard to characterize its accurate use as a simple task. To begin the process the analyst would likely start with the existing configuration of service provision facilities and then make assumptions as to how that arrangement might be improved. These initial assumptions about the best mix of facility sizes and locations can only be made after a substantial amount of regional data is qualitatively analyzed. Using the model also requires that the analyst determine what levels of disaggregation is appropriate for the analysis being performed. Further, the model requires knowledge of both GIS and statistical regression

techniques for analysis of the data after its been collected. Fortunately these issues are also of concern to the private market and have been addressed with the release of dedicated market analysis packages. A couple very promising options for the Navy are reviewed here.

The first, Huff's Market Area Planner,[98] was developed by Dr. Huff himself in conjunction with the Datametrix Corporation and offers the most comprehensive use of his model. The original bivariate model has been updated to a multivariate format to account for many other factors besides travel time and square feet of retail area. This simplifies the adjustments made to account for Navy specification issues like tax considerations and mode of travel. In using the software package the analyst is no longer required to be intimately familiar with the nuisances of accessibility measures, statistical regression techniques and GIS spatial techniques to specify, calibrate and use the model. All that is required is collecting and entering the data requested by the program (relieving the analyst of most all of the burden of determining what data is appropriate), and then review the market projections produced by the model.

Although this critique is based only on the program's advertising literature,[99] the main drawback for the Navy seems to lie in it comprehensiveness. The Navy's situation is substantially different than the commercial market. The program may not be flexible enough to account for the specification issues of the Navy. Many facilities don't even operate on a fee basis and others, at times, are

run at a deficit in the interest of the military member's general welfare. Additionally, although the program includes a mapping module, at its core it is a statistical analysis software package and not a GIS program. With only a mapping program the Navy would not be able to query the spatial information it collects in the flexible manner offered by a true GIS to account for Navy exclusive specification issues.

The second package, Arc View Business Analyst,[100] is produced by ERSI. In contrast to the Huff model, this package at its core is a GIS with market analysis features. As implied by the package's name, ERSI is also the publisher of Arc View GIS, which is widely recognized as the leading desktop GIS software package.

This may be one of this package's strongest points. By integrating GIS functions such as network and spatial analysis, the Navy would be able to spatially query the data it has collected in addition to performing statistical analysis, thus providing the capability of performing more customized analysis if required. Moreover, data would be easier to share between other Navy organizations that use GIS. Though it is not known if the Navy has adopted the use of Arc View as a matter of policy, it has been noted that many installation public works departments have begun using Arc View to accommodate their GIS needs. Thus, data cold be gathered from and shared among organizations such as Public Works and Morale Welfare and Recreation.

Data collection is also greatly facilitated with the Arc View package. Business analyst includes a feature to geo-reference addresses (such as a residential location list that could be obtained from a base housing office) to locations on a street network. Additionally, the software comes bundled with nationwide datasets for things like streets and local areas populations, thus reducing the Navy's costs to collect this data from local planning agencies and the U.S. Census Bureau. The comprehensiveness of these data sets could further allow the Navy to see how its plans fit in the context of region's private sector development patterns and projections.

The primary drawback to the Arc View package is that it doesn't have the analysis sophistication of the Huff Market Area planner. Its market analysis is based on older techniques resembling Reilly's Law or less sophisticated coverage techniques like those previously discussed. Nonetheless, it may work very well for the Navy and possibly even accommodate issues like non-revenue generating facilities even better than more sophisticated techniques. The network analyst feature provides drive time rings that could be used in conjunction with the coverage cut-off distances developed earlier in this paper. Although, as with the Huff Market Area Planner, Business Analyst was only reviewed using sales literature, Arc View specifically markets its product to both the public and private sector where the Huff Planner is strictly marketed for commercial applications.

These are not cheap solutions, but relative to the cost of data collection and developing in house solutions they represent a sound investment. Moreover, the Navy stands to become substantially more efficient and effective in the provision of MWR services if it more fully comprehends the nature and location of its customers. In short, if the Navy truly wishes to "run [its] 'businesses' much as the private sector does,"[101] these software solutions represent the tools used by the private sector.

Summary

In using accessibility measures and location theory to analyze locational problems the analyst is essentially presented with two possible options. The analysis can be developed in-house or use ready-made dedicated software solutions.

The use of ready-made software packages is simple enough that a non-specialist can use them. However, they may not explicitly address the issue that is being analyzed. Furthermore, because the program masks the assumptions of the model, the analyst may never even know that the issue being analyzed is not explicitly addressed.

Conversely, the in-house method provides a flexible approach that can be tailored specifically to the situation at had. As important, if not more important, is developing the analysis procedure which explicitly requires that each of the assumptions made in the model is acknowledged. But even though the models

presented here are considered relatively simple measures, they require a considerable amount of effort and expertise to be used effectively. However, an additional benefit to using models developed in-house is that the data generated for a locational analysis can be used for other analyses as the need arises.

Of the model options presented here, the use of Arc View Business Analyst seems to strike a middle ground between these two options that is particularly appealing. Although its market analysis features are not as sophisticated as other packages, the fact that Business Analyst is part of a true GIS presents several advantages. Probably the greatest advantage is in data transferability. Because many Navy Public Works departments are already using Arc View, data previously generated could be directly imported for the locational analysis and data that is generated specifically for the locational analysis would be available for other uses. Additionally, Arc View comes bundled with a large amount of data that would be available for other uses as well. Also, because several installation Public Works Departments are already using Arc View, product familiarity represents another advantage. GIS analysts are already familiar with the product and would not require much additional training.

The fact that Arc View is a true GIS presents yet another advantage in its flexibility. Data compiled for the locational decisions could be queried to resolve specific issues of the locational decision that may not be addressed by the more sophisticated packages.

[82] Beaumont, J. R., *GIS and Market Analysis*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 139-140.

[83] Beaumont, J. R., *GIS and Market Analysis*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 139.

[84] O'Hara, Vince, "Health Care professionals find the "right" location," *Business Geographics Volume 1, Number 5* (September/October 1993): 40.

[85] Reimer, Hans, "Easier, more affordable retail site analysis," *Business Geographics Volume 3, Number 3* (March 1995): 30.

[86] Battista, Cristina, "Competition in the food chain," *Business Geographics Volume 3, Number 3* (March 1995): 32.

[87] Parrott, R and F. P. Stutz , *Urban GIS Applications*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 247.

[88] Landis, John, "Four productivity raising business geographics applications," *Business Geographics Volume 2, Number 4* (July/August 1994): 39.

[89] Hanson, S. and M. Schwab, "Accessibility and interurban travel," *Environment and Planning A* 19 (1987): 738.

[90] Ewing, R., P. Haliyr and G. W. Page, "Getting around and traditional city, a suburban planned unit development, and everything in between," *Transportation Research Record* number 1466 (1994): 61.

[91] Robinette, A., *Land Management Applications of GIS in the State of Minnesota*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 276. and Edward J. Kaiser, David R. Godschalk, and F. Stuart Chapin, Jr., *Urban Land Use Planning* (Urbana IL: University of Illinois Press, 1995).

[92] Robinette, A., *Land Management Applications of GIS in the State of Minnesota*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 276.

[93] Talen, Emily. "Visualizing Fairness: Equity Maps for Planners." *Journal of the American Planning Association* Vol. 64 No. 1 (1998): 27.

[94] ArcView Network Analyst Product Overview (October 30, 2000). Redlands, CA: Environmental Systems Research Institute, Inc. Retrieved October 30, 2000 from: http://www.esri.com/software/arcview/extensions/netext.html

[95] Bach, L., "The Problem of Aggregation and Distance for Analyses of Accessibility and Access Opportunity in Location-allocation Models," *Environment and Planning* A 13 (1981): 968.

[96] Huff, David L. and John W. Haggerty, *Determination of Intra-Urban Retail Trade Areas*, Los Angeles: Real Estate Research Program, Graduate School of Business Administration, Division of Research, University of California Los Angeles, 1962, 23.

[97] Huff, David L. and John W. Haggerty, *Determination of Intra-Urban Retail Trade Areas*, Los Angeles: Real Estate Research Program, Graduate School of Business Administration, Division of Research, University of California Los Angeles, 1962, 24.

[98] DataMetrix - Huff's Market Area Planner (2000). Tulsa, OK: DataMetrix Inc. Retrieved October 22, 2000, from: http://www.datametrixinc.com/huffmap4.html.

[99] DataMetrix - Huff's Market Area Planner (2000). Tulsa, OK: DataMetrix Inc. Retrieved October 22, 2000, from: http://www.datametrixinc.com/huffmap4.html.

[100] ArcView Business Analyst Product Overview (August 4, 2000). Redlands, CA: Environmental Systems Research Institute, Inc. Retrieved October 22, 2000 from: http://www.esri.com/software/businessanalyst/overview.html

[101] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 6.

Chapter 5: Conclusion

This thesis has addressed how the U.S. navy might plan for the locational distribution of Morale Welfare and Recreation facilities in an environment of limited resources. From a broader academic perspective, it provides a bridge between the two academic fields of accessibility measures and market location theory. Accordingly, it serves as an example of how public agencies might address the spatial considerations of service provision. The public sector is unique in that it provides services on a cost reimbursable or no cost basis rather than a profit basis. Nonetheless, because of location theory's foundation lies in accessibility measures, which have traditionally been applied for public sector purposes, its extension of accessibility measures has viable public applications.

Ensuing studies

To fully incorporate the methods suggested by this thesis, the Navy will need to specify the goals it has outlined for regional planning. In other words, the methods of goal measurement cannot be employed until the goal is fully described. In refining both their goals and measurement procedures, the Navy may want to employ the services of a firm specializing in locational analyses.[102] A list of such firms specializing in tailored locational analysis is provided in Table 7.

Table 7: Location Analysis Consulting Firms

Applied Geographic Solutions Inc. www.appliedgeographic.com	GeoAnalytics Inc. www.geoanalytics.com
AnySite Technologies www.anysite.com	Geodezix Consulting www.geodezix.com
Business Information Technologies Inc. www.bit-co.com	Geonomics Inc. www.geonomicsinc.com
Buxton Co., The www.buxtonco.com	Harvard Design and Mapping www.hdm.com
CACI Marketing Systems www.demographics.caci.com	InfoUSA www.infousa.com
CAP Index www.capindex.com	Integration Technologies Inc. www.integtech.com
Chain Store Guide www.csgis.com	Matrix Research LLC www.matrixr.com
Channel Marketing Corp www.cmcus.com	MPSI Systems Inc www.mpsisys.com
Claritas Inc www.claritas.com	Object FX Corp. www.objectfx.com
Conclusive Strategies www.conclusivestrategies.com	PROGIS www.progis.co.at
Cuesta Systems Inc. www.cuestasys.com	RMSI www.rmsinet.com
DataMetrix Inc. www.datametrixinc.com	Siemens, S.A. -BU NET/GNS/PS www.net.siemens.pt
Descartes Systems Group www.descartes.com	Spatial Insights Inc. www.spatialinsights.com
Digital Engineering Corp. www.digitalcorp.com	SRC www.extendthereach.com
DMTI Spatial Inc. www.dmtispatial.com	Statistics Canada www.statcan.ca
EI Technologies LLC www.eitek.com	Staubach www.staubach.com
eMapping Solutions Inc. www.emappingsolutions.com	Tactician Corp. www.tactician.com
Empower Geographics www.empowergeo.com	Tangram Corp. www.tangram-corp.com
Equifax Compusearch www.polk.ca	TELUS Geomatics www.telusgeomatics.com
ESRI Inc. www.esri.com	Thompson Associates www.thompsonassociates.com
Generation 5 Data Modeling and Statistical Analysis Inc. www.generation5.net	

Source: *Location Analysis Puts Businesses in Their Place*. (2000, June). Not available: Business Geographics. Retrieved November 10, 2000 from: http://www.geoplace.com/bg/2000/0600/0600loc.asp.

At the outset of this investigation, a singularly optimal solution to the Navy's location decision was sought. However, this goal was forfeited because of two primary factors: 1) the Navy's desire to emulate private practices and 2) the indeterminate nature of facility location decisions. Although location theory is the focus of this research, other of fields of knowledge were noted that provide promise in finding a method to derive a singularly optimal solution. Accordingly, the Navy may wish to pursue additional research in these fields.

Multiple Objective Programming provides a possible means of optimizing the several possibly conflicting objectives (increasing access while cutting costs) of the location problem.[103] If the location problem could be reduced to a set number of equations greater than the number of unknowns (facility location, facility size, requirement for a facility etc.), the equations could be solved using a simple linear program using features of common spreadsheet software packages. However, the permutations of possible facility location and sizes provides alone provides an almost infinite number of variables. Furthermore, balancing equations in common units is a difficult task[104] since the costs and benefits derived are often measured differently. For example, it is difficult to measure the cost of a consumer's travel to a retail outlet against the utility they receive from that journey. While quantifying the costs of operations is a relatively practical accounting task[105] measured in dollars, as with all utility functions measuring the customer's utility has a weak theoretical foundation.[106] Moreover, even if the

utility could be properly measured, it still must be expressed in common units with operation cost to form a program. It may be that as with location theory, which uses retail areas and travel impedance to describe the locational problem, surrogate measures (possibly including accessibility) could be used to identify a singularly optimal solution. This thesis and the references given in Table 8 are provided as a starting point for exploration of these issues:

Table 8: Multiple Object Programming Titles

Title	Author	Year
Algorithms for nonlinear programming and multiple-objective decisions	Rustem, Berc & Chichester	1998
Multi-objective programming and goal programming : theories and applications	Berlin	1996
Multiobjective optimization: behavioral and computational considerations	Ringuest, Jeffrey L	1992
Dynamic selection of models	Rutledge, Geoffrey William	1995
Advances in multiple objective and goal programming : proceedings of the second International Conference on Multi-Objective Programming	International Conference on Multi-Objective Programming and Goal Programming	1996

Similarly, game theory, which evolved out of artificial intelligence, may be able to handle the Navy's locational problem in a more sophisticated manner offering a fully optimal solution. Algorithms using in game-theory software written in the programming language C, "can assess the perceived value of traversing down individual branches in a decision tree, determine the best possible

branches, step down a level or tow to the favored branches and assess the possibilities all over again."[107]

Concluding remarks

In reevaluating the way that planning is done, the Navy has embarked on a long journey toward cultural change. This work charts one possible course for that journey. The Navy, however, is not alone on that journey. Similar pressures have been exerted on the public sector at large to increase services while cutting cost.[108] And, to a large extent, the private sector also joins the public sector in seeking to cut costs while maintaining contact with their customers. Consequently, both by the pubic sector and the private sector, much work has been done upon which the Navy can draw in the continued charting of its course.

At its heart, Regional Planning asks if economies of scale can be realized through consolidation while maintaining acceptable access to and provision of support services. For its fiscal aspects, Regional Planning carries on its shoulders the weight of the public trust. Through Regional Planning, the Navy is affirmatively seeking to leverage the public's investment for maximum return. Furthermore, for MWR facilities in particular, Regional Planning bears the responsibility of the Navy to care for its sailors and marines. Facility issues are large than questions of bricks and mortar. They impact the lives of facility users and operators alike. For these reasons, the level of success that Regional Planning

attains will provide valuable insight to the possibilities available to the public sector.

Regional Planning requires the Navy to change both organizationally and operationally. As has been discussed, Regional Planning requires a multidisciplinary approach to operations and cannot be implemented by any single organization such as the Naval Facilities Engineering command or the Morale, Welfare and Recreation organization. Maintaining access to facilities requires the contribution of both service provision and facilities location.

It also requires the replacement of rigid criteria with more flexible techniques like those employed by business. The validity of this work rests heavily on this point. Facility criteria like those in the Navy Facility Planning Criteria Manual, which as a rule account for only one specification issue the base population, are not in keeping with "state-of-the art market business practices"[109] and are not in the best interest of the Navy. The needs of the Navy can only be served if they are acknowledged. Thus, more flexible measures like (though not necessarily) accessibility and location theory, which acknowledge relevant rather than predefined specification issues need to be implemented. Drawing on the Naval Facilities Engineering Command's planning responsibilities in general, this need calls for planned solutions rather than engineered solutions.

The implementing Regional Panning is no small undertaking. However, although the methods presented here do not constitute a definitive course, they do demonstrate that viable techniques are available to implement Regional Planning.

"Let the journey begin."

[102] Orzel, Chris, Tony Lea, and Rachel Crain. *Cashing in on Market Potential.* (2000, September). Not available: Business Geographics. Retrieved November 10, 2000 from: http://www.geoplace.com/bg/2000/0900/0900ct.asp

[103] Interview with William W Cooper, Professor Emeritus, DSC, University of Texas at Austin: Department of Management Science and Information Systems, Austin, TX 19 October 2000

[104] Telephone interview with Dave Ranson, Branch Head Naval Personnel Command, Navy MWR Facilities and Acquisition Base Navy MWR Facilities and Acquisition (NPC 656), Millington, TN. 17 October 2000

[105] Telephone interview with Dave Ranson, Branch Head Naval Personnel Command, Navy MWR Facilities and Acquisition Base Navy MWR Facilities and Acquisition (NPC 656), Millington, TN. 17 October 2000

[106] Voges, E. M. and A. H. Naude, "Accessibility in urban areas: an overview of different indicators," National Institute for *Transport and Road Research, SCIR, PO Box 396, Pretoria 0001* (October 1983): pg 8.

[107] Daniel, Larry, "Going fro maximum market coverage – beyond canned software," *Business Geographics Volume 2, Number 4* (July/August 1994): 52.

[108] Savas, E. S. Privatization: *Privitization: The Key to Better Government* (Chatham, NJ Chatham House Publishers, 1987) and Osborne, Davide and Ted Gaebler, *Reinventing Government: How the Entrepreneurial Spirit is Transforiming the Public Sector.* (Reading, MA: Addision-Wesley Publishing, 1992).

[109] U. S. Department of the Navy, Deputy Chief of Naval Operations (Logistics), *21st Century Shore Support Infrastructure Vision and Strategic Plan* (Washington, D. C., 24 June 1997), 3.

Listing of Bibliographic Materials

Agyemang-Duah K and Hall FL. "Spatial Transferability of an Ordered Response Model of Trip Generation" *Transportation Research A 31(5)*, (1997): 389-402.

ArcView Network Analyst Product Overview (October 30, 2000). Redlands, CA: Environmental Systems Research Institute, Inc. Retrieved October 30, 2000 from: http://www.esri.com/software/arcview/extensions/netext.html

Bach, L. "The Problem of Aggregation and Distance for Analyses of Accessibility and Access Opportunity in Location-allocation Models." *Environment and Planning* A 13 (1981): 955-978.

Battista, Cristina. "Competition in the food chain." *Business Geographics Volume 3, Number 3* (March 1995): 32-34.

Baxter, R. S. and G. Lenzi. "The measurement of relative accessibility." *Regional Studies* 9 (1975): 15-26.

Beaumont, J. R., *GIS and Market Analysis*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 139-151.

Ben-Akiva, M and S. R. Lerman. "Disaggregate travel and mobility choice models and measures of accessibility." *Behavioral Travel Modeling* (1979) Eds E A hensher, PR Sopher (Croom Helm, Andover, Hants): 654-679.

Breheny, M. J. "The Measurement of Spatial Opportunity in Strategic Planning." *Regional Studies* 12 (1978): 463-479.

Bucklin, L. P. "Shopping Patterns in an Urban Area." Berkeley, CA: Institute of Business and Economic Research, 1967.

Cowen, D. J. and W. L. Shirley. *Integrated Planning Information Systems*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 275-283.

Daniel, Larry. "Enhanced modeling helps position business geographics in the retail industry." *Business Geographics Volume 1, Number 5* (September/October 1993): 37-39.

DataMetrix - Huff's Market Area Planner (2000). Tulsa, OK: DataMetrix Inc. Retrieved October 22, 2000, from: http://www.datametrixinc.com/huffmap4.html.

Davidson, K. B. "Accessibility and Isolation In Transport Network Evaluation." Australia: Davidson Transport Consulting, 1980.

Ewing, R., P. Haliyr and G. W. Page. "Getting around and traditional city, a suburban planned unit development, and everything in between." *Transportation Research Record* number 1466 (1994): 53-62.

Forkenbrock, David J. and Lisa A Schweitzer. "Environmental Justice In Transportation Planning." *Journal of the American Planning Association* Vol. 65 No. 1 (1999): 96-111.

Guy, C. M. "The assessment of access to local shopping opportunities: a comparison of accessibility measures." *Environment and Planning B: Planning and Design* 10 (1983): 219-238.

Handy, S. L. "Regional Versus Local Accessibility: Neo-Traditional Development and Its Implications for Non-Work Travel." *Built Environment* 18(4) (1993): 253-267.

Handy, S. L., and D. A. Niemeier. "Measuring Accessibility: An Exploration of Issues and Alternatives." *Environment and Planning* A 29 (1997): 1175-1194.

Hansen W. G. "How accessibility shapes land use." *Journal of the American Institute of Planners 25* (1959): 73-76.

Hanson, S. "The determinants of daily travel-activity patterns: relative location and sociodemographic factors." *Urban Geography* 3 (1982): 179-202.

Hanson, S. and M. Schwab. "Accessibility and interurban travel." *Environment and Planning A* 19 (1987): 735-748.

Hardcastle D and I. Cleeve. "Accessibility Modeling Using GIS." in Geographic Information Systems: Proceedings of Seminar N held at the PTRC European Transport Forum, University of Warwick, England (1995): 400.

Hazel GM. "The development of a disaggregate trip generation model for the strategic planing control of large foodstores. 2. Measuring accessibility and designing the trip generation model" *Traffic Engineering and Control 29(2)*, (1988): 95-103

Huff, David L. and John W. Haggerty. *Determination of Intra-Urban Retail Trade Areas.* Los Angeles: Real Estate Research Program, Graduate School of Business Administration, Division of Research, University of California Los Angeles, 1962.

Ingram, D. R. "The Concept of Accessibility: A Search for an Operational Form." *Regional Studies* 5 (1971): 101-107.

Kaiser, Edward J., David R Godschalk and F. Stuart Chapin, Jr. *Urban Land Use Planning; Fourth Edition* (Urbana and Chicago Illinois: University of Illinois Press, 1995).

Kitamura, Ryuichi and M. Kermansha. "Sequential models of interdependent activity and destination choice." *Transportation Research Record* number 987 (1984): 81-89.

Knox, P. L. "The Intraurban Ecology of Primary Medical Care: Patterns of Accessibility and Their Policy Implications." *Environment and Planning* A 10 (1978): 415-435.

Koening, J. G. "Indicators of urban accessibility: theory and application." *Transportation* 9 (1980): 145-172.

Kostyniuk, Lidia P. and Ryuichi Kitamura. "Trip Chains and Activity Sequences: Test of Temporal Stability." *Transportation Research Record* number 987 (1984): 29-39.

Lakshmanan, T. R. and Walter G Hansen. "A Retail Market Potential Model." *American Institute of Planners Journal* (May 1965): 134-143.

Landis, John. "Four productivity raising business geographics applications." *Business Geographics Volume 2, Number 4* (July/August 1994): 39-41.

Martinez F J. "Access: the transport-land use economic link" *Transportation Research B 29(6)*, (1995): 457-470

Morris, J. M., Dumble, P. L., and Wigan, M. R. "Accessibility Indicators for Transport Planning." *Transportation Research* A 13A (1979): 91-109.

Navy and Marine Corps Shore Installations, Facility Planning Criteria, P-80. (1998, March). Norfolk, VA: NAVFAC Criteria Office Engineering Innovation Division, Atlantic Division, Naval Facilities Engineering Command. Retrieved June 9, 2000 from: http://www.efdlant.navfac.navy.mil/Lantops_20/P-80/p80.htm

O'Hara, Vince, "Health Care professionals find the "right" location," *Business Geographics Volume 1, Number 5* (September/October 1993): 40-41.

Osborne, Davide and Ted Gaebler, *Reinventing Government: How the Entrepreneurial Spirit is Transforiming the Public Sector.* (Reading, MA: Addision-Wesley Publishing, 1992).

Orzel, Chris, Tony Lea, and Rachel Crain. *Cashing in on Market Potential.* (2000, September). Not available: Business Geographics. Retrieved November 10, 2000 from: http://www.geoplace.com/bg/2000/0900/0900ct.asp

Parrott, R and F. P. Stutz, *Urban GIS Applications*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 247-260.

Pirie, G. H. "Measuring Accessibility: A Review and Proposal." *Environment and Planning* A 11 (1979): 299-312.

Reid, Hal. "Defining trade areas or trying to see the invisible." *Business Geographics Volume 3, Number 3* (March 1995): 46-47.

Reilly, William J. *The Law of Retail Gravitation.* New York: Pilsbury Publishers, 1953

Reimer, Hans. "Easier, more affordable retail site analysis." *Business Geographics Volume 3, Number 3* (March 1995): 30.

Robinette, A., *Land Management Applications of GIS in the State of Minnesota*, in *Geographical Information Systems, Volume 2: Applications*, ed. David J. Maguire, Michael F. Goodchild and David W. Rhind (New York: John Wiley & Sons, Inc., 1992), 275-283.

Savas, E. S. Privatization: *Privitization: The Key to Better Government* (Chatham, NJ Chatham House Publishers, 1987)

Savigear, F. "A Quantitative Measure of Accessibility." *Town Planning Review* 38 (1967): 64-72.

Sherman, L., B. Barber and W. Kondo. "Method for evaluating metropolitan accessibility." *Transportation Research Record* number 499 (1974): 70-82.

Talen, Emily. "Visualizing Fairness: Equity Maps for Planners." *Journal of the American Planning Association* Vol. 64 No. 1 (1998): 22-38.

Tipp, Jason. *Geodemographic Data Provide Qucik Answers to Retail Questionsl.* (2000, July/August). Not available: Business Geographics. Retrieved November 10, 2000 from: http://www.geoplace.com/bg/2000/0800/0800ma.asp

U. S. Department of Defense. *Defense Acquisition (NOTAL), DOD Directive 5000.1.* 15 March 1996.

U. S. Department of the Army. U. S. Army Engineers, Construction Engineering Research Laboratories. *Determining an Army Installations Critical Requirements (CORE) USACERL Technical Report FF-95/07.* March 1995.

U. S. Department of the Navy. Chief of Naval Operations. *Environmental and Natural Resources Program Manual, OPNAVINST 5090.1B.* Washington, D. C., 1 November 94.

U. S. Department of the Navy. Chief of Naval Operations. *Responsibility for Shore Activity Missions, Functions and Tasks, and Organization Instructions (NOTAL), OPNAVINST 5450.171C.* Washington, D. C.

U. S. Department of the Navy. Chief of Naval Operations. *Command Responsibility for Shore Land and Facilities Planning, OPNAVINST 11000.16A CH-1.* Washington, D. C.

U. S. Department of the Navy. Chief of Naval Operations. *Base Loading Projections for Shore Activities Planning and Programming (NOTAL), OPNAVINST 11010.37.* Washington, D. C.

U. S. Department of the Navy. Deputy Chief of Naval Operations (Logistics). *21st Century Shore Support Infrastructure Vision and Strategic Plan.* Washington, D. C., 24 June 1997.

U. S. Department of the Navy. Naval Facilities Engineering Command. *Shore Facilities Planning Manual: A System for Planning of Shore Facilities, NAVFACINST 11010.44E*. Washington, D. C., 15 December 1987.

U. S. Department of the Navy. Naval Facilities Engineering Command. *Navy Facilities Assets Data Base Management System Procedures Manual, NAVFAC P-78*. Washington, D. C.

U. S. Department of the Navy. Naval Facilities Engineering Command. *Comprehensive Regional Planning Instruction, Overview*. Washington, D. C., March 2000.

U. S. Department of the Navy. Naval Facilities Engineering Command. *Comprehensive Regional Planning Instruction, Regional Shore Infrastructure Planning Instruction*. Washington, D. C., March 2000.

Verroen, E. J., and H. D. Hilbers. "Urban Planning and Mobility, Some Dutch Experiences." Netherlands: TNO Institute for Infrastructure, 1996.

Voges, E. M., and A. H. Naudé. "Accessibility in Urban Areas: An Overview of Different Indicators." South Africa: Technical Report RT/21/83, National Institute for Transport and Road Research, CSIR, 1983.

Wachs, M., and T. G. Kumagi. "Physical Accessibility as a Social Indicator." *Socio-Economic Planning Science* 7 (1973): 437-456.

Weibull J W, "On the numerical measurement of accessibility" *Environment and Planning A 12* (1980): 53-67.

Weibull, J. W. "An Axiomatic Approach to the Measurement of Accessibility." *Regional Science and Urban Economics* 6 (1976): 357-379.

Wickstrom, G. V. "Defining Balanced Transportation – A Question of Opportunity." *Traffic Quarterly* 25 (1971): 337-350.

Wilson, A. G. "A Family of Spatial Interaction Models, and Associated Developments." *Environment and Planning* 3, (1971): 1-32.

Vita

Charles Emery Bowers was born in Washington, Pennsylvania on February 14, 1969, the son of Dorothy Louise Bowers and Charles Malvern Bowers. After completing his work at Trinity High School, Washington, Pennsylvania in 1987, he entered George Washington University in Washington, D. C. During the fall of 1988 he entered to the Pennsylvania State University in University Park, Pennsylvania. He received the degree of Bachelor of Science in Mechanical Engineering from the Pennsylvania State University in January 1992.

Upon graduation, he was commissioned as an officer in the United States Navy, Civil Engineer Corp through The Pennsylvania State University, NROTC. During the following years he was assigned by the Navy to the Resident Officer in Charge of Construction Office at Naval Air Station Sigonella, Sicily, Naval Mobile Construction Battalion FIVE, homeported in Port Hueneme, the Defense Language Institute in Monterey, CA and U. S. Forces Azores on the island of Terceria, Azores, Portugal. Additionally, he holds an Engineer in Training Certificate from the Minnesota State Board of Architecture, Engineering, Land Surveying, Landscape Architecture and Interior Design, awarded in March of 1993.

In September 1999 she entered The Graduate School at The University of Texas.

Permanent Address: 2140 South Main Street Extension

Washington, Pennsylvania 15301

The author typed this thesis.